PRELIMINARY REPORT
FOR
COMMONWEALTH OF PUERTO RICO
DEPARTMENT OF PUBLIC WORKS
AND
PUERTO RICO PLANNING BOARD

FLOOD CONTROL STUDIES
HUMACAO RIVER
HUMACAO, PUERTO RICO

CESAR S. CANALS ASSOCIATES

CONSULTING ENGINEERS

APRIL, 1969

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CESAR S. CANALS ASSOCIATES

April, 1969

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June 8, 1970

Hon. Antonio Santiago Vázquez
Secretary of Public Works
Santurce, Puerto Rico

Re: Humacao River Flood Control Study. Contract No. 69-116, Preliminary Report

Dear Sir:

In compliance with the contract in reference between César S. Canals Associates and the Department of Public Works, dated October 11, 1968, we are submitting herewith the preliminary report on the "Flood Control Study of the Humacao River."

We have received the cooperation of your staff and of other Commonwealth and Federal Government Agencies in the performance of this work.

We gratefully appreciate the opportunity of participating in these studies and thank you and your staff for the valuable assistance extended.

Respectfully submitted,

CESAR S. CANALS ASSOCIATES

José A. Beniamino

JOSE A. BENIAMINO, M. S. C. E.
Registered Professional Engineer

Enclosure

FLOOD CONTROL STUDIES
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HUMACAO, PUERTO RICO

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CONCLUSIONS AND RECOMMENDATIONS

The flood situation in Humacao at present is critical and a feasible flood control program should be started immediately to prevent a recurrence of the 1960 catastrophe. The plan recommended in this study would provide positive protection for the 100-year flood and a flood similar to the September 1960 flood. The implementation of this plan will require further study and planning to produce construction plans. Meanwhile, the following preventive measures should be taken that would greatly alleviate the flood situation.

1. Clean the present river channel from the bridge on Route 30 to the mouth, removing all debris and vegetation other than grass.
2. Clear the mouths of the main river channel and of the overflow channel of sandbars and maintain them open to provide ready flow of flood waters to the ocean.
3. Remove all the remaining piers and decks of the old bridges and any other obstructions in the channel such as the culvert type pedestrian crossing built recently upstream from the bridge on Route 3.
4. Develop a program of inspection and maintenance to

keep the present channel clean, until the proposed new channel is constructed. These inspections should be done periodically, particularly during the summer months before the start of the hurricane season. Maintenance of the channel should include the removal of any bamboo growths or any other such vegetation growing in the channel or on the banks immediately adjacent to it, and more frequent cleaning of the side ditches used for local drainage.

5. The construction of the new Highway PR-3 across a wide expanse of the Humacao River flood plain should be coordinated with the execution of the channelization works recommended herein. (See route location on Plate 19).

It should be noted that the construction of an earth embankment for this road will serve as a dike endangering the lands upstream and that enough waterway should be provided to pass the design discharge under the existing conditions through any bridge built over the Humacao River if the new road is built prior to the channelization. Our recommendations pertaining to the subject is that either construction of any embankment for this road be

done simultaneously with the construction of the channel or that the road be built over a trestle across the flood plain to provide the optimum waterway to pass a flood of the magnitude of the 1960 flood.

Three alternate floodway schemes were studied as follows: (See Plate 26).

Plan A - Single channel approximately following present river alignment, no overflow channel with twin jetties, with the mouth of the river very close to the existing overflow channel mouth where the sea is deeper (See Plates 15A and 26).

Plan B - Single channel approximately following present river alignment with overflow channel in the lower floodplain.

No jetties required. (See Plate 15B and 26)

Plan C - Single channel aligned approximately to the east side of the proposed Humacao south by-pass. With mouth of the river close to the existing mouth. Jetties required. (See Plates 15C and 26).

A feasibility study and the design for the construction of the

recommended plan, namely Plan B, should be started as soon as possible. The plan recommended, Plan B, provides the following.

1 - A new completely realigned river channel with a compound section consisting of a main channel for normal flow and a floodway on each side of the channel formed by earth levees to the point where the main existing channel meets the existing overflow channel.

2 - Construction of a new river channel and a new overflow channel from the above mentioned point to the ocean.

3 - Relocation of Route 923 and construction of a new bridge on this route over the Cataño Creek and the proposed channel.

4 - Construction of an access road from existing Route 923 to the triangular area of land formed between the new river channel and the new overflow channel with a bridge to carry the road over the river channel.

5 - Construction of floodwalls on both sides of the river from the upstream face of the bridge on Route 3, to a point upstream from the section known as "Patagonia".

6 - Relocation of the Mariana Creek across existing Route 3 to a point in the river about 230 meters downstream from the existing bridge on route 3.

7 - Construction of a new bridge on Route 3 over the relocated Mariana Creek channel.

8 - Construction of a debris fence at a section upstream from "Patagonia" to prevent sugar cane and bamboo trees from being washed into the stream.

9 - Construction of a debris deflector at about 74 + 91 to deflect floating debris from the channel into an area between the river channel and a small brook flowing in at this point.

10 - Excavation of new channel for the Cataño and Mabú Creeks as shown on the location and topographic map in the Appendix and Plate 23.

The economic advantage of this plan over Plan "A" is approximately $681,000 and over Plan C $2,219,778. Our recommendations are based on this economic advantage and also on the following:

A large area of land lying north of the present overflow channel drains through it at present. It is therefore necessary to keep it open so as to prevent the area from becoming swampy. Likewise, the main river channel drains a large portion of the southern end of the flood plain and of the hills lying to the south. The flood plain is so flat that it would be impossible to drain these areas to the

overflow channel unless extensive earthfill work is done to provide adequate slope. Therefore, the river channel should be kept open through these reaches at least until this area is developed.

Another advantage of the plan is that it does not require the construction of jetties at the mouth of the channels, as is the case with Plan "A. and Plan "C", because during major floods, if the mouths are partially obstructed, the excees floodwaters will spill over the triangle of land formed by the channels and flow out to the sea.

Although it is not the purpose of this study to estimate the feasibility of this program, we have computed in an approximate manner the benefits that would accrue from the construction of these works and have found that:

1 - A large extension of buildable land around the city of Humacao would be made available to local builders for housing construction. Thisis in line with a study by the Planning Board for the expansion of this eastern area of the Island.

2 - During the 1960 flood 5,000 acres of land were inundated for a loss of $600,000. Damages to over 1,000 private dwelling and other buildings were estimated at close to $900,000. Damages to roads and bridges were about $650,000. Large areas of sugar cane land were damaged severely by sedimentation produced by the erosion of uplands and an estimated 140 persons lost their lives when their homes were washed away.

About 250 acres of land to be reclaimed by this project could be developed as soon as the river works are completed for housing at a density of approximately 6.5 houses per acre.

The average house in this area would sell for about $15,000, which would produce a gross revenue of $22,000,000.

A recurrence of the 1960 flood would inflict damages upon the area of over $2,000,000. Since the cost of Plan "B" is $7,453,000, the benefit to cost ratio based on the above amount is: 3.34 to 1.0. These figures do not include the value of lives that would be saved as these cannot be evaluated in dollars and cents.

Based on the foregoing figures and conclusions, we recommend that Plan "B" be adopted, as being the more expeditious and economical plan to protect the area from dangerous flooding.

To establish a safe and reasonable amount of protection, several hypothetical floods and the historical flood of record were considered, as follows:

The Standard Project Flood: It is not practical to assign a frequency to the Standard Project Flood, but the six-hour point rainfall for such a storm would have a frequency in excess of 200 years.

The flood of September 5 and 6, 1960, was found to have a

larger peak discharge than the 100-Year Flood. After the backwater curves for the proposed new channel were computed, it was found that it was not economically feasible to provide full protection for the Standard Project Flood. The backwater profiles in the Appendix show a difference of approximately 1.0 meter in elevation between the Standard Project Flood and the 1960 Flood and a difference of 0.60 meters between the latter and the 100-Year Flood. Considering that most bridges over a stream are designed by the Bureau of Public Roads for the 50-Year Flood with a freeboard of 1.5 meters, the existing bridges over the Humacao River and any new bridges built in the future would pass these two floods with some head on the upstream side without overtopping the deck. To pass the Standard Project Flood with a minimum freeboard of 1.0 meter would require raising or widening the bridge of Route No. 3.

Although the Standard Project Flood could occur at any time, it actually occurs very rarely and full protection in the channel for this event would be very costly. The recommended procedure is to protect for a lesser flood in the channel, place the top of floor slabs of future buildings above the Standard Project Flood by approximately 0.5 meter and install pressure flap valves on all pipes draining into the streams.

TEXT OF REPORT

INTRODUCTION

Authority for Report

This report was authorized and is submitted under the terms of an agreement dated December 30, 1968, between the Department of Public Works of the Commonwealth of Puerto Rico and César S. Canals Associates, Consulting Engineers, Santurce, Puerto Rico.

Purpose of Report

The studies presented in this report were undertaken to determine the extent of flooding in low lying areas of the city of Humacao and adjacent areas affected by the floodwaters of the Humacao River and to develop a feasible and economical plan for controlling said flooding, and to serve as the basis for the preparation of zoning regulations, and of construction plans and specifications for the control structures required for the protection of the above-mentioned areas.

Scope of Report

The studies reported herein were carried to the preliminary design stage of the control works. The recommended plan of action outlined in the report evolved from studies of several plans of improvements and control which were developed, analyzed and evaluated. (See Plate 26).

Hydrologic studies were made in sufficient detail to establish the design flood flows. The hydraulic calculations and the preliminary design calculations for levees and other structures involved in the plans were carried only far enough to arrive at approximate quantities of work items for the preparation of preliminary estimates of cost.

The report makes recommendations for determining minimum finished grade for those areas that are now being considered by the Planning Board for urban development.

Scope of Studies

The following items were considered in these studies:

1. Effect of rainfall and runoff, tides and hurricanes; runoff detention; sedimentation; debris catchments; channel alignment and slopes.
2. Hydrologic, soils and vegetative conditions in the basin to develop flood design and frequency of occurrence.
3. The maximum channel capacity of the existing waterways was determined by backwater computations.
4. Possible water impoundment as a means of reducing peak discharges downstream.
5. Hydraulic design of large closed conduits working under pressure as a means of clearing sand deposits that accumulate at the mouth of the river.

6. Preparation of preliminary cost estimates of alternate schemes and determination of those possibilities that appear most feasible and merit further study.

7. Preliminary recommendations as to finished grade of those areas proposed for urban development to the Planning Board and awaiting approval of the Board.

By direction of the Planning Board a plan of protection was investigated that proposed the canalization of the river channel and the building of earth levees through the city limits and beyond to the point where the proposed relocation of Route 923 would cross the channel. From this point to the ocean the river channel would be left as it is at present without any improvements. This plan has the disadvantage that it does not offer complete protection, because the present river channel does not have the capacity to carry runoff from large floods safely to the sea. During the larger floods the waters would spread over a large area of sugar cane at floodplain and create a higher backwater effect along the reaches through the city limits. This would require raising the tops of the proposed levees to a higher elevation. This plan is considered rather expensive for the limited amount of protection it offers.

Prior Reports

1. "Flood Plain Information, Humacao River, Puerto Rico", a report prepared by the Corps of Engineers, Jacksonville

District, Jacksonville, Florida, dated August, 1966.

2. "Special Storm Report, Storm of September 5, 6, 1960, Humacao River Watershed, Puerto Rico", prepared by the U. S. Department of Agriculture, Soil Conservation Service, San Juan, Puerto Rico.

3. "Floods at Humacao, Puerto Rico," by Miguel A. López of the U. S. Geological Survey, San Juan, Puerto Rico, dated 1967.

Other Sources

Information for six-hour maximum recorded rainfall was obtained from the Hydrology Guide Handbook of the U. S. Department of Agriculture Soil Conservation Service. Information for the 50 and 100-Year six-hour rainfall was obtained from the U. S. Weather Bureau Technical Paper No. 42. Information on soils was obtained from Soils Maps of the Division of "Tasación Científica" of the Department of the Treasury of the Commonwealth of Puerto Rico. The type of the vegetative cover in the region was obtained from these maps and by field trips to the watershed.

Acknowledgements

During the preparation of this report we received cooperation and information from the following agencies and consultants:

Department of Public Works, Commonwealth of Puerto Rico

Puerto Rico Planning Board

Land Administration of Puerto Rico

Puerto Rico Aqueduct and Sewer Authority

Municipal Government of Humacao

U. S. Soil Conservation Service

U. S. Weather Bureau

U. S. Geological Survey

Corps of Engineers

Puerto Rico General Archives

Guillermety & Ortíz, Consulting Engineers

Bussman Associates, Consulting Engineers

The cooperation and information received is gratefully acknowledged.

THE FLOOD SITUATION IN HUMACAO

Description of Area:

The city of Humacao, located about 50 kilometers southeast of San Juan, on the easterly end of the island, lies along the banks of the Humacao River. The river rises in the upper slopes of the Sierra de Cayey and meanders in an easterly direction through the city along a narrow, shallow channel.

The drainage area of the river consists of about 25.6 square miles of land partly covered by tropical forest at the headwaters and planted in minor crops and sugar cane in the wider valley areas upstream and downstream from the city. The lower end of the basin is a flat and wide floodplain that borders the Vieques Passage on the Caribbean Sea. The total present population of the basin is about 40,000 persons, but population is growing at a fast rate and according to forecasts of the Puerto Rico Planning Board it is expected that it will reach 60,000 by 1985.

The horizontal spread of the city is such that a large percent of the population will be housed in close proximity to the river and unless building construction in the floodplain is restricted, or the river channel is improved to permit the passage of flood peak discharges, another catastrophe similar to the one caused by the passage of hurricane Donna in 1960, can be expected to occur at any time.

The Humacao River is a small stream with a normal depth of flow of a few inches, but during flash storms or hurricane rains the river can turn into a raging torrent in a matter of a few hours. This is caused by the fact that the river drops very rapidly from an elevation of 300 meters to 15 meters in 20 kilometers and its time of concentration is extremely short.

The soils of the uplands of this river basin are mostly soils classified by the Soil Conservation Service as Hydrologic soil cover complex Group "C" which are shallow soils and soils containing considerable clay and colloids with below average infiltration after pre-saturation. The clayey nature of these upland soils makes them rather impermeable, runoff producing and very susceptible to sliding when wet. During the flood of September 1960, large amounts of these soils covered with vegetation were washed down the river and deposited in the channel. The sugar cane was rolled into windrows that together with large bamboo trees, were washed down to the bridge sites and blocked the waterways almost completely.

The Flood of Record:

The maximum known flood of record occurred in September 5 and 6, 1960, caused by the passage of hurricane "Donna" eighty five miles off the northeast coast of Puerto Rico. Although the hurricane winds missed the Island, the torrential rains that followed produced the

most disastrous floods ever experienced in this area. As a result of this extraordinary rain the Humacao River overtopped its banks, flooded some 3,600 acres of land and claimed 90 lives lost and 30 persons missing. The urban and agricultural damage was heavy due to the very high velocities of the floodwaters of the river and of its three main tributaries, namely: the Mariana, Cataño and Mabú Creeks. The Soil Conservation Service estimated that some 60,000 tons of sediment were transported by the river into the sugar cane fields causing serious damage to the crops. Property damages from this flood in the Humacao area were reported to be well over two million dollars.

Other Floods:

Another large and damaging flood occurred on August 27, 1961, as a consequence of another tropical hurricane. This flood inundated approximately 1,300 acres of land and though not as destructive and large in magnitude as the September 1960 flood, it came just one year after and served as a reminder that events of this nature can happen at any time, as long as channel conditions remain unimproved.

Two major hurricanes were registered in Puerto Rico prior to 1960, that also inflicted severe damage to the island. These were: "San Ciriaco" in 1899 and "San Felipe" in 1928.

"San Ciriaco", one of the most destructive hurricanes, entered the Island from the east-southeast coast and traversed it in a north-

northwest direction. The port of Humacao was greatly damaged by the passage of this storm. The total damages in the southeastern region of the Island were estimated at approximately two million dollars.

"San Felipe", considered by many as the most destructive hurricane experienced in the Island, crossed it in an east-southeast to north-northwest direction on September 13, 1928, and produced many of the maximum rainfalls of record. However, no evidence of flood water marks was uncovered in Humacao for either of these two occurrences by our investigations.

Flood Damages:

The flood damages that would result today from recurrences of major known floods would be even more severe that heretofore because of the present condition of the river channel. The 1960 flood destroyed all the bridges crossing the Humacao River except for the bridge on State Route 923. The bridge on Route 3 that was destroyed by the 1960 storm has been replaced by a larger and higher structure that will pass the peaks from large floods safely. However, the piers of the four railroad bridges that were destroyed downstream from the Route 3 crossing still remain in place and are completely covered with bamboo trees and other vegetation. Photographs in the Appendix to this report illustrate the conditions of these piers and of the present river channel.

The bridge on State Route 923 although spared by the 1960 flood was destroyed during the May 21, 1969 flood. (See photographs). During

the 1960 flood this bridge was blocked by trash and sediment and the flood waters overtopped it and spilled into the sugar cane fields depositing large amounts of sediment that damaged the crop of that year. After careful consideration given to the future street layouts for the town of Humacao (See Planning Board Plan dated January 13, 1969) where three bridges are proposed to cross the Humacao River, it is recommended that the construction of the most easterly bridge be accelerated and rerouting of State Route 923 along higher grounds across this bridge be effected. (See Plate 19).

The strong winds of hurricane "Donna" in 1960, produced very high waves that retarded the discharge of the river into the sea. This condition is being made worse nowadays by the extraction of sand from the protective sandbar and the beach existing on both sides of the mouth of the river.

The Humacao River carries a relatively large load of sediment even at normal flow that starts depositing downstream from the bridge on Route 3 due to the flatness of the channel, the numerous meanders, and the effect of the tide. The river borne sediment plus the sand deposited by the litoral drift form a sandbar that keeps the mouth of the river completely blocked. In times of flood the river discharge becomes greater than the tidal storage and opens a channel through the sandbar, but in so doing, the river builds up a head, overflows its banks and floods the adjacent lands.

Hurricane Tides:

There are no records of tidal observations made during hurricanes along the eastern coast of the Island. In the available reports on severe hurricanes of record, little mention is made of tidal inundations. The major loss of life has been from drownings, wind destruction, and floods.

Wave Action:

The only reliable information concerning wave action was obtained on two occasions during 1962. High water marks ranging to about three meters were observed along the northern coast of Puerto Rico. Both of these incidents were occasioned by winter type, low pressure centers in the North Atlantic.

Tidal Flooding:

Damage from hurricanes in Puerto Rico appear to be limited to winds and flooding from the torrential rainfall produced by the hurricanes. Most records of hurricane damages make little mention of tidal inundations along the coast. The tidal flooding that has occurred in the past has been limited to the marsh areas behind the low coastal ridge. In the Humacao River Basin the area subject to this type of flooding lies north of the river channel and east of the now abandoned railroad alignment. It is less than a square mile in area.

TOPOGRAPHY AND SOILS

The topography of the Humacao River basin varies from the steep slopes in the uplands of the Sierra de Cayey where it rises to the gently sloping floodplains between the city of Humacao and the Caribbean Sea. Plates 18A, 18B, 18C, 19 and 20 show the topography along the project length of the river.

Soils of the upland are Cayagua sandy clay loam, Jayayes silty clay loam, Pandura loam, Las Piedras loam, Humacao loam, Daguao clay, and Mucara silty clay loam.

Most of these soils are classified in hydrologic group "C". These are runoff producing soils and when wet are susceptible to landslides.

The subsoils in the reaches of the project are better described by the soils boring logs and seismic profiles shown on Plates 7 and 8.

There is no firm bedrock present above a depth of 35 feet below the ground surface. The soils in station 17 + 12 are interpreted as a moist sandy silty clay complex increasing in degree of compactness with increasing depth.

The soils in station 47 + 20 are interpreted as a saturated silty clayey sand complex exhibiting the characteristic increase in degree of compactness with depth.

The soils at station 56 + 89 varies from loose sand at 4.3 feet to hard clay at 30.3 feet.

Those on station 76 + 21 vary from coarse sand and silty sand to descomposed rock at 20.0 feet.

These soils were found to be suitable for levee construction when well compacted and can be excavated readily to form the river channel using motor scrapers. Because of their granular nature these subsoils should not present difficulties for motor scraper operations.

The soil information discussed in this section was obtained from maps of the U. S Department of Agriculture, maps of the Division of Land Appraisal of the Commonwealth of Puerto Rico and from profiles plotted from seismic refraction surveys expressly made for this report.

HYDROLOGY

Method of Computing Flood Discharge

Hydrologic computations of runoff for the flood considered in this report were made using a procedure indicated in the "Hydrology Handbook" of the Soil Conservation Service of the U. S. Department of Agriculture. Synthetic hydrographs computed by this procedure appear in the Appendix to this Report (See Plates 9, 10, 11) for the Standard Project Flood, the Intermediate Regional or 100-Year Flood, the 50-Year Flood, the 25-Year Flood and the Historical Flood of record which occurred in September 5-6, 1960.

The drainage area of the Humacao River, comprising about 25.6 square miles of land, has been subdivided into two sub-watershed areas for the purpose of this report. Sub-watershed Area 1 includes river drainage area to a point opposite the start of the most densely populated section of the city. This area totals 10.8 square miles. Sub-watershed Area 2 includes the urban section of the city and the flat lands all the way to the ocean. This area covers 14.8 square miles.

Rainfall data for six-hour point rainfall information for Puerto Rico was obtained from the U. S. Weather Bureau Publication "Technical Paper No. 42", except for the precipitation data on the Historical Flood of Record which was taken from the Isohyetal Maps shown on Plates 5

and 6, prepared by the Soil Conservation Service from records of the Weather Bureau office at San Juan for the storm of September 5-6, 1960. Analysis of these records, as compared with the backwater elevations depicted in the publication of the U. S. Corps of Engineers Atlas H. A.-265 showed that the discharges obtained from highwater marks by the U. S. Corps of Engineers could not be caused by the run off produced by the amount of rainfall recorded for this date. The reason for the high water marks obtained was that the bridges were clogged with vegetation and debris at the time of the flood reflecting higher water marks than the ones that would have been obtained if the bridge waterways had been completely operational. Reference is made to the publication "Special Storm Report, Storm of September 5, 6, 1960, Humacao River Watershed, Puerto Rico" prepared by the U. S. Department of Agriculture Soil Conservation Service where a similar statement is made by the Service hydrologists that investigated the 1960 flood.

The Humacao River watershed area (See Plate 2) includes approximately 16,400 acres of land of which 15,000 are in the upland areas and 1,400 acres are in the flood plain area. The upland areas are planted mostly in sugar cane, pasture and woodland. The flood plain is planted mostly in sugar cane.

The soil maps of the Commonwealth Division of Land Appraisal indicate that the upland soils are of the Cayagua sandy clay loam, Jayuya loam, Pandura loam, Mucara silty clay type and others generally

classified in Hydrologic Soil Group "C".

The computations yielded a weighted soil cover complex number of 77, for antecedent Moisture Condition II, and number 92 for Moisture Condition III. Antecedent Moisture Condition II is generally the average condition prevailing during the annual flood period. Condition III prevails when heavy rainfalls have occurred during the five-day period immediately preceding the given storm.

In the case of the September 5-6, 1960 flood, Moisture Condition II was used to compute the synthetic hydrograph in the Appendix because our investigations disclosed that heavy rainfalls had not occurred during the five days preceding the storm. For the graph of the Standard Project Flood, Antecedent Condition III was used to meet the definition of the "Standard Project Flood" which describes it as being the flood that may be expected from the most severe combination of meteorological and hydrological conditions that are considered reasonably characteristic of the geographical area in which the drainage basin is located. Peak discharge for these floods are generally about 40% to 60% of the Maximum Probable Flood for the same basin. Such floods as used by the U.S. Corps of Engineers are intended as practicable expressions of the degree of protection that should be sought in the design of flood control works. The synthetic runoff hydrograph of the Maximum Probable Flood for the basin, rainfall and runoff information from these hydrographs being shown in the following table:

Flood Runoff Hydrograph	Tributary area (Sq. Mi.)	6-Hr. Point Rainfall (Inches)	Antecedent Moisture Condition	Peak Discharge (Sec.-Ft)	Location
Standard					At river
Project	25.6	15.5	III	50,750	Mouth
100-Year	25.6	10.5	III	32,335	Mouth
50-Year	25.6	9.2	III	27,975	Mouth
25-Year	25.6	8.1	III	24,390	Mouth
Sept. 5-6, 1960	25.6	12.3	II	40,000	Mouth

HYDRAULIC ANALYSIS

Present Situation:

At present, flash floods of the Humacao River inundate the adjacent lands on both sides of its banks. The flood situation is aggravated by the fact that the channel is shallow and narrow, with insufficient capacity for passing flood peaks. The lower reaches of the river is a shallow estuary with two outlets to the sea. One outlet enters the sea about in line with Cayo Batata, near Morro de Humacao. The other is an overflow channel that enters the sea about 1,000 meters north of the first.

Both outlets are closed by sand accretion most of the time due to the prevalence of the tidal and wave action over the sluggish river flow. El Morro de Humacao, a rock promontory that extends into the sea south of the outlet forms a natural groin that promotes the deposition and accumulation of the sand and silt carried by the river and the littoral drift. It is clearly visible from the photographs in the Appendix that the mouths of this estuary cannot be kept open by the low flow of the river. In times of flood, when the river discharge is greater than the tidal storage, it will overcome the tide and open a channel through the sandy bottom to the sea; but in so doing, the river builds up a head, overflows its banks and floods the area.

Several schemes were considered to alleviate the flood situations. (See Plate 25). The possibility of building detention reservoirs (See Plate 24) was one of the schemes investigated, but it appears that the only reservoir that could be created in the upper portion of the river at a reasonable cost would have a capacity of only about 800 acre-feet which is so small that its influence on the flood regime would be insignificant. A large reservoir downstream of the location of the above-mentioned reservoir would be very costly. Even considering the reduction in cost of the channel improvements in the lower part of the river, the cost of retention reservoirs would be prohibitive. It was determined that the only possible solution for the flood problem in Humacao is to provide a channel to the sea that will carry safely the peak runoffs from storms of large magnitude.

To determine the economically feasible amount of protection to be provided, a hydrological study of the basin was made and synthetic runoff hydrographs of four hypothetical and one actual storm were computed.

The hypothetical storms were the 25-Year, the 50-Year, the 100-Year or Intermediate Regional Flood, and the Standard Project Flood. The actual storm computed was the Historical Flood of Record for the Humacao River that occurred September 5-6, 1960.

The method used to develop these hydrographs was discussed

in the section on Hydrology of this report.

Backwater curves of these floods were routed through a proposed channel with a compound section consisting of a normal flow section excavated in the existing ground and two floodways made up by the construction of earth levees on both river banks. These computations were made using the methods of the Corps of Engineers described in their technical manual EM-1110-2-1409 entitled "Backwater Curves in River Channels". These methods are based on the equation of continuity and the Manning equation for flow in river channels. Routing through proposed bridges was done assuming three feet diameter round piers.

Although no records are available on hurricane tides, for the purpose of computing the backwater elevations, the assumption was made that the river peak discharge at the mouth was entering the sea over a two meter high wave.

Plate No. 16 in the Appendix shows water level profiles obtained by these computations. These water level elevations were used to determine the most economical height of levees. Velocities in the channels and floodway reaches were obtained from them also.

Local drainage of areas alongside the river that are at present before the Planning Board awaiting preliminary approval would be effected if we consider the times of concentration of the areas involved. A design rainfall of short duration was selected with a time to peak for the river estimated considering the entire runoff from the farthest point on

the river watershed. Under this condition the project rainfall would occur on the urban areas in the floodplain prior to the arrival of the peak discharge from the mountains. These areas proposed for housing development are shown on the maps in the Appendix on Plate 17 as cross-hatched areas include the proposed Regional College of the University of Puerto Rico. It is recommended that floor level elevations for houses on these developments be a minimum of 0.5 meter above Standard Project Flood elevation.

Slope and Channel Bottom Protection

Protection from erosion will have to be provided in the reaches of the realigned channel where the velocities exceed ten feet per second for the Standard Project Flood. Local stone would make rip-rap protection practical and economical. Channel side slopes and bottoms may also have to be rip-rapped or protected in the confluences of the river tributaries, near and under bridges and in the reaches where the above velocity is exceeded. Slope rock revetment should be extended a reasonable distance below the channel bed to prevent undermining by bottom scour. We have used this type of protection for estimating purposes but there are several other ways to provide slope protection that are used in the United States and that could be used here successfully at a considerable saving in cost. The choice of method should be dictated by the materials found around the area. If the channel and surrounding terrain is gravelly,

it would be economical to use sacked concrete protection.

If the terrain is bouldery and rocky grouted rip-rap protection would be the method to use. The State of California has made extensive studies on this matter and uses all kinds of slope protection, from grass seeding to old automobiles. The amount of maintenance that will be given to these areas also has a direct bearing on which type of protection to use.

It is recommended that a more extensive investigation into this matter be made prior to deciding on final construction design for slope protection.

Control Structures

Because of the relatively high velocities that will be generated by the larger floods, sand, rocks and boulders could easily be transported through the channel, causing damage to any mechanical type of gates or movable controls. Therefore, the control structures to be used should be simple in design. The specific details of these structures were not considered an essential part of this report. The designs of structures were made in just enough detail to produce preliminary quantities for estimating. Some of these structures should be model tested before final designs are adopted.

The aid of such agencies as the Corps of Engineers, the U.S. Coast and Geodetic Survey and the Bureau of Reclamation should be enlisted for this purpose.

ALTERNATE WORKS CONSIDERED

In trying to effect economics in a project of this nature, several alternate plans of improvement have to be considered. On the Humacao River study only three of them were found to merit final investigation. All schemes considered aim to convey the surplus water during mayor storms at an cinreased rate directly to the sea. One of them diverts part of the water through an additional channel beginning at a point in the floodplain where the river reaches become very flat. The other plans considered were contingent on building a flood control reservoir upstream and had to be discarded shen a suitable site for it could not be found.

The plans presented here, and shown on Plate 26 are based on building enlarged channel cross sections for more hydraulic capacity, easing of bends in the river and provviding lines or smoother surfaces ro reduce resistance to water flow; also providing a combined floodway section with an excavated channel and earth levees.

All plans will require the use of leeves on both sides of the channel because of the compound alluvial section requited. In the design of an alluvial channel subject to seasonal floods the section consists of a main channel for normal flow and a floodway on each side formed by levees to pass the peaks from the larger accurrences. This design have the advantage that self cleansing velocities can be maintained in the river during normal flow.

At present the existing channels are blocked by sandbars along the shoreline.

The Humacao River continuosly transports large quantities of sediments from the highlands to the floodplain. Plan "B" assumes that little or no maintenance of the channel would be provided and has been designed to pass the major floods at the lower end of the river mostly through the floodplain. Plan "A" and plan "C" would require more frequent cleaning and maintenance of the channel to function as intended in its design. How much more maintenance and at what price is difficult to evaluate properly at this time.

For the purpose of this Report we are making our recommendations on the basis of first cost obtained from our preliminary estimates.

It shall be noted that subquent feasibility studies may result in a combination of the plans presented herein.

Plan A: This plan, (shown on Plate 15-A), contemplates the construction of an enlarged river channel and a floodway bounded by levees from the mouth of the existing overflow channel (Lago S lado), where the sea is deeper to the bridge of route No. 3. From this point on to the bridge on route 30, the same compound section is used with a narrower channel which requires the retainment of levees.

Removal of the sand bar at the mouth of the existing overflow channel will be required and the construction of twin jetties at this mouth to maintain discharge capacity by preventing shoaling at the mouth.

Plan B: This plan, presented in plates 15-B and 18-B, 19, 20, is basically the same improved as in Plan A, except for the lower part of the river, where it branches into two separate channels bounded by two levees, following the routes of the existing river channel and of the existing overflow channel (Lago Salado). The most significant advantage of this plan is that it does not contemplate the use of jetties because in the case of extraordinary floods the shoreline and the land between the two channels would serve as emergency floodway making the conveyance of future floods expeditiously to the ocean; regardless of the conditions of the moths of the channels at the time of the flood without affecting the upstream areas. This cheme will require less maintenance of the outlets and the estimated cost of construction is less than any of the other plans considered. It retains most of the river present alignment, thus eliminating the adquisition of additional lands for right of way and it do not requires the construction of a costly storm sewer system to handle the waters that are naturally drained by gravity.

The main disadvantage of this plan is that it will divide, as it presently is, the commercial from a residential area of the town, thus requiring the eventual construction of additional bridges over the river when the integration of these areas is deemed desirable.

Access would have to be provided to the land between the channels so it can continue to be cultivated as at present or if acquired by the Commonwealth Government, converted into a park, beach resort and recreation area.

Structures built in this area would have to be raised above present ground approximately three meters to permit the passage of a Standard Project Flood.

Plan C: This plan, which is shown on Plates 15-C and 18C considers an improved channel relocated adjacent to the east side of the proposed Humacao south by-pass, now undergoing final design and construction to begin in a very short time.

This improved channel will extend from route No. 30 to the present mouth. The construction of two jetties of steel sheet pile celular construction will be required to prevent shoaling of the river mouth, similar to Plan A. Additional and more extensive studies are necessary prior to implementing a plan of this nature where practically the entire regimen of the river is changed.

The main advantage of this plan is that it will provide for an integrated development southward of the city of Humacao which is very desirable.

This plan requires extensive cut through hardpan and rock and the purchase of substantial lands for the right-of-way and for storage of excavated material prior to filling the present river channel.

The proposed Humacao south by-pass highway overpasses road No. PR-908 in an area southwest of Patagonia Housing, a clover-leaf interchange having been designed. Routing of the proposed channel between this structure and the southwest corner of Patagonia Housing could

require the purchasing of many properties of the Patagonia Housing.

The construction of the Humacao south by-pass highway, as well as the Humacao Regional College would be seriously delayed by the implementation of this plan since it will require a more detailed study, for which funds could not be readily allocated.

The economical advantages of this plan is that 42 acres of land in the central Humacao district would be released for housing and commercial construction.

Town houses, apartments, single-family dwellings and commercial buildings could be built that would probably bring in a gross revenue of approximately $8,000,000.

The direct connection between the Humacao central district and the southern area plus the urban enhancement that would be effected by this plan are some of the intangible benefits that will accrue to the city of Humacao.

Of the schemes considered, this is the most expensive one.

require the purchasing of many properties of the Patagonia Housing.

The construction of the Humacao south by-pass highway, as well as the Humacao Regional College would be seriously delayed by the implementation of this plan since it will require a more detailed study, for which funds could not be readily allocated.

Of the schemes considered, this is the most expensive one.

PRELIMINARY ESTIMATES OF COST

Preliminary estimates of cost for the three plans discussed in this report were made, taking into consideration the construction facilities of the Humacao area. The availability of stone for rip-rap, concrete aggregates, ready mix concrete and ready manpower has been noted.

For the channel excavation it was assumed that motor graders could be used advantageously and the same equipment would dump the material on the levee sites. The channel excavation in the ocean was assumed to be done by a small hydraulic dredge.

Estimates of quantities for earthwork were taken from cross sections prepared from elevations and distances obtained from U. S. Geological Survey quadrangle maps. Right-of-way lands were measured from these maps. These are approximate quantities and not to be used for construction purposes. More detailed studies and quantities taken from maps prepared to larger scales will be required for construction plans and estimates.

Prices for these preliminary estimates were obtained from projects of a similar nature being constructed in other parts of the Island for the Department of Public Works. A contingency item equal to 20% of the total computed cost has been added to these estimates to compensate for the lack of more detailed information. Cost of the lands for right-of-ways

was obtained from appraisals of similar lands in other areas.

Preliminary Estimates of Cost for Plans "A", "B", and "C", are shown in the tables that follow.

CONSTRUCTION COST ESTIMATE
FOR
PRELIMINARY REPORT ON FLOOD CONTROL
HUMACAO RIVER

*ALTERNATE PLAN "A"

No.	Description	Units	Quantities	Unit Price	Amount
1	ROW				
	(a) Urban Areas	CDS	83	$ 3,000	$ 249,000
	(b) Rural Areas	CDS	140	1,500	210,000
	(c) Buildings	EA	64	3,000	192,000
	(d) Crops & Damages	L.S.	20% of Rural Lands		42,000
2	Clearing & Grubbing	CDS	223	300	66,900
3	Stripping & Storing Topsoil	C.M.	60,000	0.70	42,000
4	Removal of Existing Structures or Obstructions	L.S.			100,000
5	Channel Excavation	C.M.	553,000	2	1,106,000
6	Additional Levee Compaction & Shaping	C.M.	300,000	0.60	180,000
7	Miscellaneous Fill in Abandoned Meanders				
	(a) From Channel Excavation	C.M.	253,000	0.30	75,900
	(b) From Borrow Sources	C.M.	190,000	1.50	285,000
		C.M.	358,470	1.25	448,100
8	Excavation for Structures	C.M.	1,500	8	12,000
9	Class "A" Concrete	C.M.	1,000	80	80,000
10	Stone Revetment	Tons	190,000	6.50	1,235,000
11	Seeding - Borinquen Bermuda Grass	S.M.	168,000	0.70	118,000
12	Planting Grass - Malojillo or Pangola	S.M.	85,000	0.60	51,000
13	Jetties				
	(a) Steel Sheet Piles	Lb.	156,000	0.20	31,200
	(b) Driving Piles	L.F.	39,000	5	195,000
	(c) Stone Fill	Ton	6,690	7.50	50,200
14	Debris Catcher	L.S.	1		10,000
15	Debris Fence	L.F.	1,000	20	20,000
16	Relocation of Route 923	Km.	2.5	400,000	1,000,000
17	Bridge on Route 923	S.F.	8,500	30	255,000
18	Bridge over Cataño Creek	S.F.	3,230	30	97,000
19	Bridge over Mariana Creek	S.F.	4,200	30	126,000
					$6,257,300
			Contingencies 20%		1,251,460
			TOTAL		$7,508,760

*Channel through present river overflow only with 2 steel sheet pile cofferdam jetties at the mouth.

CONSTRUCTION COST ESTIMATE
FOR
PRELIMINARY REPORT ON FLOOD CONTROL
HUMACAO RIVER

*ALTERNATE PLAN "B"

Item No.	Description	Units	Quantities	Unit Price	Amount
1	ROW				
	(a) Urban Areas	CDS	83	$ 3,000	$ 249,000
	(b) Rural Areas	CDS	140	1,500	210,000
	(c) Buildings	EA.	64	3,000	192,000
	(d) Crops & Damages	L.S.	20% of Rural Land		42,000
2	Clearing & Grubbing	CDS	223	300	66,900
3	Stripping & Storing Topsoil	C.M.	60,000	0.70	42,000
4	Removal of Existing Structures or Obstructions	L.S.			100,000
5	Channel Excavation	C.M.	633,000	2	1,266,000
6	Additional Levee Compaction & Shaping	C.M.	300,000	0.60	180,000
7	Miscellaneous Compacted Fill in abandoned Meanders				
	(a) From channel excavation	C.M.	333,000	0.30	99,900
	(b) From borrow excavation	C.M.	119,000	1.50	178,500
8	Excavation for Structures	C.M.	1,500	8	12,000
9	Class "A" Concrete	C.M.	1,000	80	80,000
10	Stone Revetment	Tons	190,000	6.50	1,235,000
11	Seeding - Borinquen Bermuda Grass	S.M.	168,000	0.70	118,000
12	Planting Grass - Malojillo & Pangola	S.M.	85,000	0.60	51,000
13	Debris Catcher	L.S.	1		10,000
14	Debris Fence	L.F.	1,000	20	20,000
15	Relocation of Rte. 923	Km.	2.5	400,000	1,000,000
16	Bridge on Route 923	S.F.	8,500	30	255,000
17	Access Road & Bridge to Area between channel	S.F.	5,420	30	163,000
18	Access Road to Area	L.S.			100,000
19	Bridge over Cataño Creek	S.F.	3,230	30	97,000
20	Bridge over Mariana Creek	S.F.	4,200	30	126,000
					$5,893,300
			Contingencies 20%		1,178,660
			TOTAL		$7,071,960

*Channel through present river and overflow, no jetties.

CONSTRUCTION COST ESTIMATE
FOR
PRELIMINARY REPORT ON FLOOD CONTROL
HUMACAO RIVER

*ALTERNATE PLAN "C"

Item No.	Description	Units	Quantities	Unit Price	Amount
1	ROW				
	(a) Urban Areas	CDAS	63	$ 3,000.00	$ 189,000.00
	(b) Rural Areas	CDAS	134	1,500.00	201,000.00
	(c) Buildings	EA.	15	3,000.00	45,000.00
	(d) Crop Damages	L.S.	20% of Rural Lands		40,200.00
2	Clearing & Grubbing	CDS	197	300.00	59,100.00
3	Stripping & Storing Topsoil	C.M.	100,000	0.70	70,000.00
4	Removal of Existing Structures	L.S.	1	80,000.00	80,000.00
5	Channel Excavation	C.M.	775,000	2.00	1,550,000.00
6	Additional Levee Compaction & Shaping	C.M.	260,000	0.60	156,000.00
7	Fill on abandoned meanders				
	(a) From Channel Excavation	C.M.	515,000	$\frac{135}{120}$ x .30	154,000.00
	(b) From Borrow Sources	C.M.	360,000	1.50	540,000.00
8	Excavation for structures	C.M.	1,500	8.00	12,000.00
9	Class "A" Concrete	C.M.	3,100	80.00	248,000.00
10	Stone Revetment	Tons	200,000	6.50	1,300,000.00
11	Seeding - Borinquen Bermuda Grass	S.M.	200,000	0.70	140,000.00
12	Planting Grass Malojillo or Pangola	S.M.	85,000	0.60	51,000.00

CONSTRUCTION COST ESTIMATE
FOR
PRELIMINARY REPORT ON FLOOD CONTROL
HUMACAO RIVER

*ALTERNATE PLAN "C"
(continued)

Item No.	Description	Units	Quantities	Unit Price	Amount
13	Debris Catcher	L.S.	1	$ 10,000.00	$ 10,000.00
14	Debris Fence	L.F.	1,000	20.00	20,000.00
15	Relocation of Route 923	Km.	2.5	400,000.00	1,000,000.00
16	Bridge on Route 923	S.F.	8,500	30.00	255,000.00
17	Bridge over Cataño Creek	S.F.	3,230	30.00	96,900.00
18	Bridge on Route 3	S.F.	8,500	30.00	255,000.00
19	Bridge on Route 908	S.F.	8,500	30.00	255,000.00
20	Jetties				
	(a) Steel Sheet Pile	Lb.	156,000	0.20	31,200.00
	(b) Driving Pile	L.F.	39,000	5.00	195,000.00
	(c) Stone Fill	Ton	6,690	7.50	50,175.00
21	Local Drainage System - Class "A" Concrete				
	(a) 6' x 9' Conc. Box Culvert	C.Y.	3,969	80.00	316,800.00
	(b) 5' x 6' Conc. Box Culvert	C.Y.	3,254	80.00	260,320.00
	(c) Islets	Ea.	33	750.00	24,750.00
	(d) 30" Conc. Pipe Laterals	L.F.	2,500	9.50	23,750.00
	(e) Box culvert excavation	C.M.	44,235	2.50	110,588.00
	(f) Excavation laterals	C.M.	1,133	2.50	2,832.00
			SUB-TOTAL		$7,743,115.00
			Contingencies 20%		1,548,623.00
			TOTAL		$9,291,738.00

*Channel completely realigned.

An area will have to be provided to store excavated material (until completion of new channel) prior to filling present river channel

PROPOSED DEVELOPMENT AREAS

The proposed flood control works will release a large number of acres for housing development in the Humacao area. This future development is in line with the policies of the Puerto Rico Planning Board for the expansion of this eastern region of the island.

At present there are a few projects that have been submitted to the Planning Board for approval. Some of these are located in areas susceptible to flooding by the Humacao River and others could be endangered by tidal and wave action.

The locations of these proposed developments are shown in the Appendix on Plate 17 and are numbered 1 to 8, including the proposed Regional College of the University of Puerto Rico which would be very much affected under Plan "C".

Plate 17 also indicates preliminary minimum house floor elevations based on present channel conditions and those that may be used after the flood protection program recommended herein is implemented.

On proposed developments near the coast, a minimum floor elevation of 3.0 meters is recommended for protection against extraordinary floods and possible tidal wave effects. Areas marked 4, 5, 6, 7, and 8 can be released for development by the Planning Board if the minimum floor elevations recommended in this report are used.

It is also recommended that a detailed hydrologic study of each area be undertaken by the builders prior to the design of final drainage works and submitted to the Planning Board for approval. To drain these areas by gravity and avoid pumping, the development should be governed by the water surface profiles for the river channel developed in this report. Consideration of times of concentration of these areas versus river time of concentration would also effect economies in the final drainage design of these future developments.

APPENDIX

ABSTRACT

TITLE:	Flood Control Planning Study for Humacao
AUTHOR:	César S. Canals Associates
SUBJECT:	Flood Control Study
DATE:	April, 1969
LOCAL PLANNING AGENCY:	Puerto Rico Planning Board, Commonwealth of Puerto Rico
SOURCE OF COPIES:	Puerto Rico Department of Public Works, Santurce, Puerto Rico
HUD PROJECT NO.:	Urban Planning Grant Contract #PR P-15
SERIES NO.:	N. A.

ABSTRACT: The studies were undertaken to determine the most feasible and expeditious plan to protect the city of Humacao and other adjacent areas from flash floods of the Humacao River. The work included hydrologic studies of past and possible future floods, a hydraulic analyses of the present river channel and the proposed improved channel section, backwater computations to determine heights and velocities of these occurrences, preliminary design of channel sections, earth levees, proposed bridges,

floodwalls, debris catchments, debris fences, and slope protection. Preliminary estimates of construction costs were made, using actual figures for recent flood control projects being built in other parts of the Island.

Plates showing synthetic flow hydrographs, flood water profiles, rainfall curves, channel sections and improvements are shown in the appendix.

The report includes special recommendations for a program to improve the present river channel to provide immediate protection prior to the implementation of the proposed plan. These immediate works could prevent the recurrence of a catastrophe similar to the one caused in this area by the flood of September, 1960.

A preliminary benefit to cost ratio analysis was computed in these studies for project justification. It is recommended in the report that detailed studies using more

reliable information be undertaken to develop final construction plans. Some of the structures required for development of the plan will have to be model-tested to evaluate their functionability.

THE PREPARATION OF THIS REPORT WAS FINANCED IN PART THROUGH AN URBAN PLANNING GRANT FROM THE DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT, UNDER THE PROVISIONS OF SECTION 701 OF THE HOUSING ACT OF 1954 AS AMENDED.

COMMONWEALTH OF PUERTO RICO
DEPARTMENT OF PUBLIC WORKS
& PUERTO RICO PLANNING BOARD

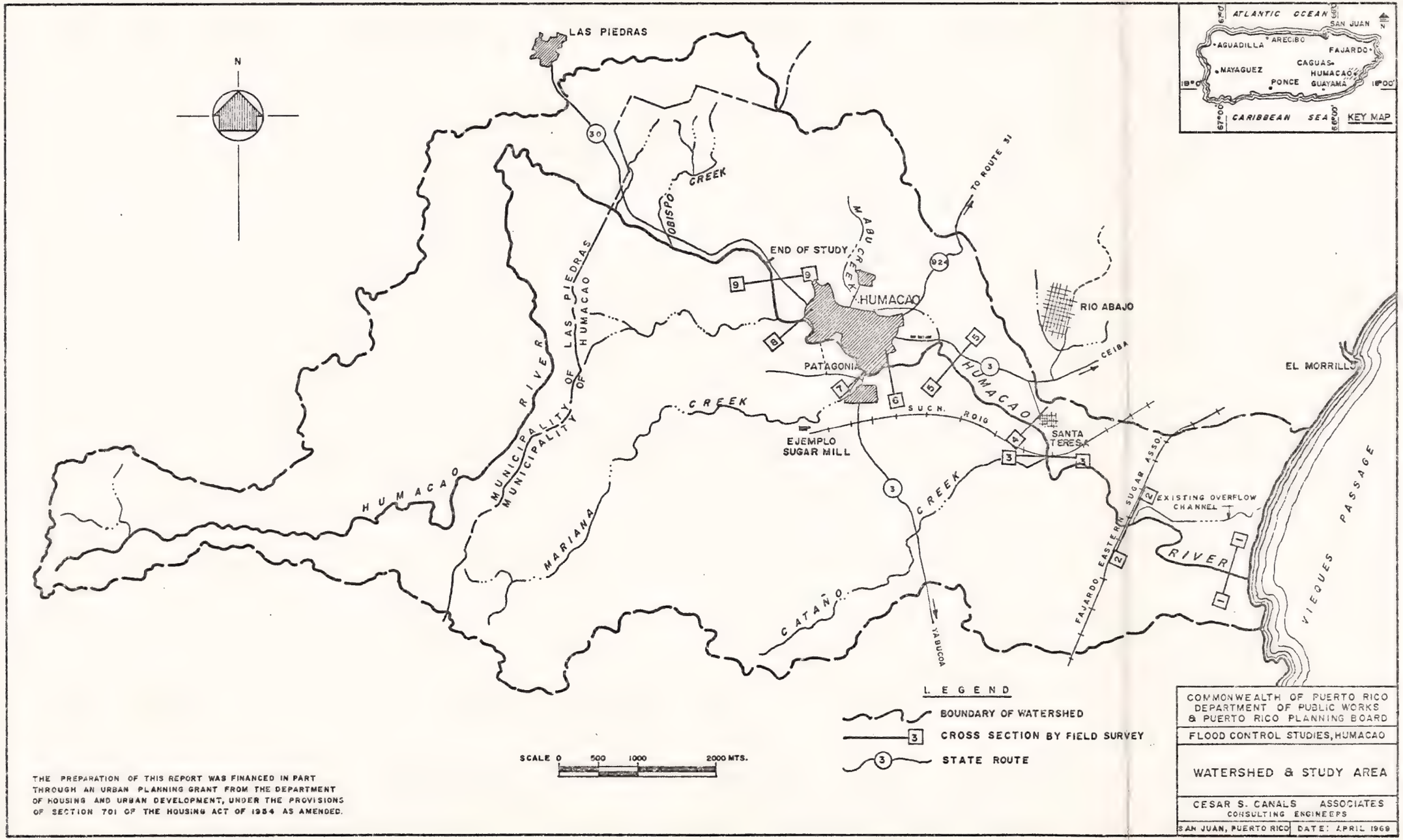
FLOOD CONTROL STUDIES, HUMACAO

HUMACAO AND VICINITY
FLOODED AREAS

CESAR S. CANALS ASSOCIATES
CONSULTING ENGINEERS
SAN JUAN, PUERTO RICO

DATE: APRIL 1969

PLATE 1



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COMMONWEALTH OF PUERTO RICO
DEPARTMENT OF PUBLIC WORKS
& PUERTO RICO PLANNING BOARD

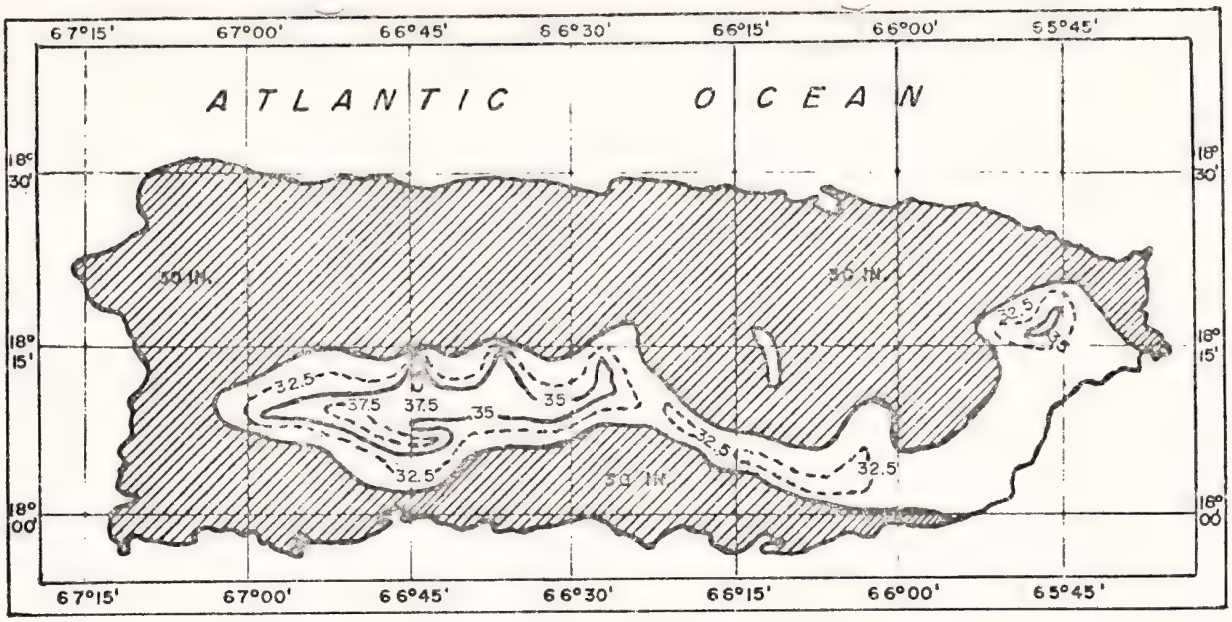
FLOOD CONTROL STUDIES, HUMACAO

WATERSHED & STUDY AREA

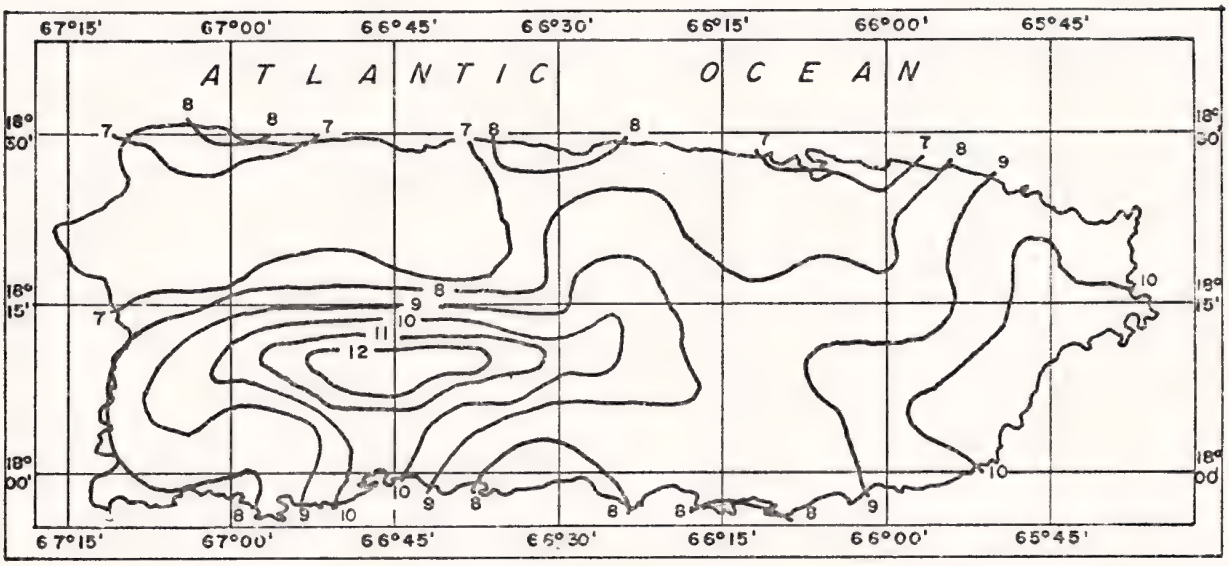
CESAR S. CANALS ASSOCIATES
CONSULTING ENGINEERS

SAN JUAN, PUERTO RICO | DATE: APRIL 1969

PLATE 2



PROBABLE MAXIMUM 6-HOUR PRECIPITATION



100-YEAR 6-HOUR RAINFALL (IN.)

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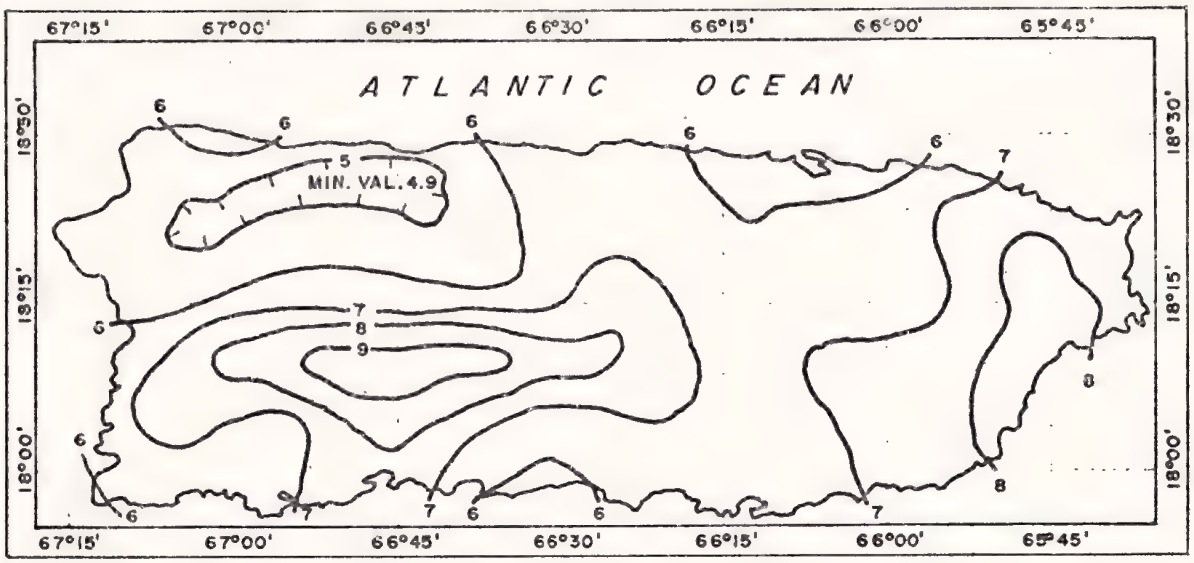
COMMONWEALTH OF PUERTO RICO
DEPARTMENT OF PUBLIC WORKS
& PUERTO RICO PLANNING BOARD

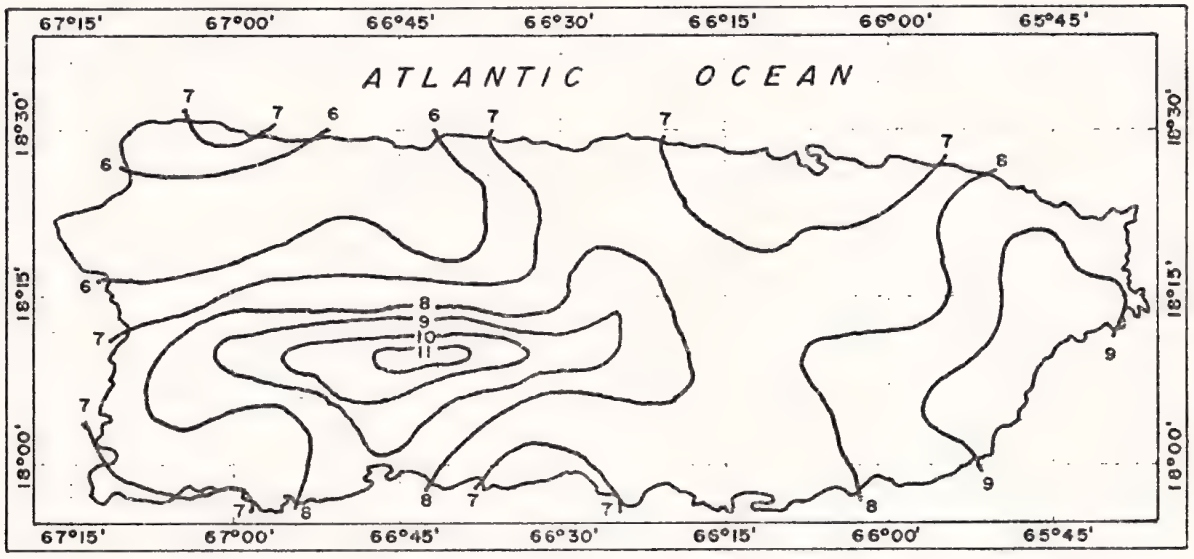
FLOOD CONTROL STUDIES, HUMACAO

PROBABLE MAXIMUM & 100-YEAR RAINFALL IN PUERTO RICO

CESAR S. CANALS ASSOCIATES
CONSULTING ENGINEERS
SAN JUAN, PUERTO RICO | DATE: APRIL 1959



25-YEAR 6-HOUR RAINFALL (IN.)



50-YEAR 6-HOUR RAINFALL (IN.)

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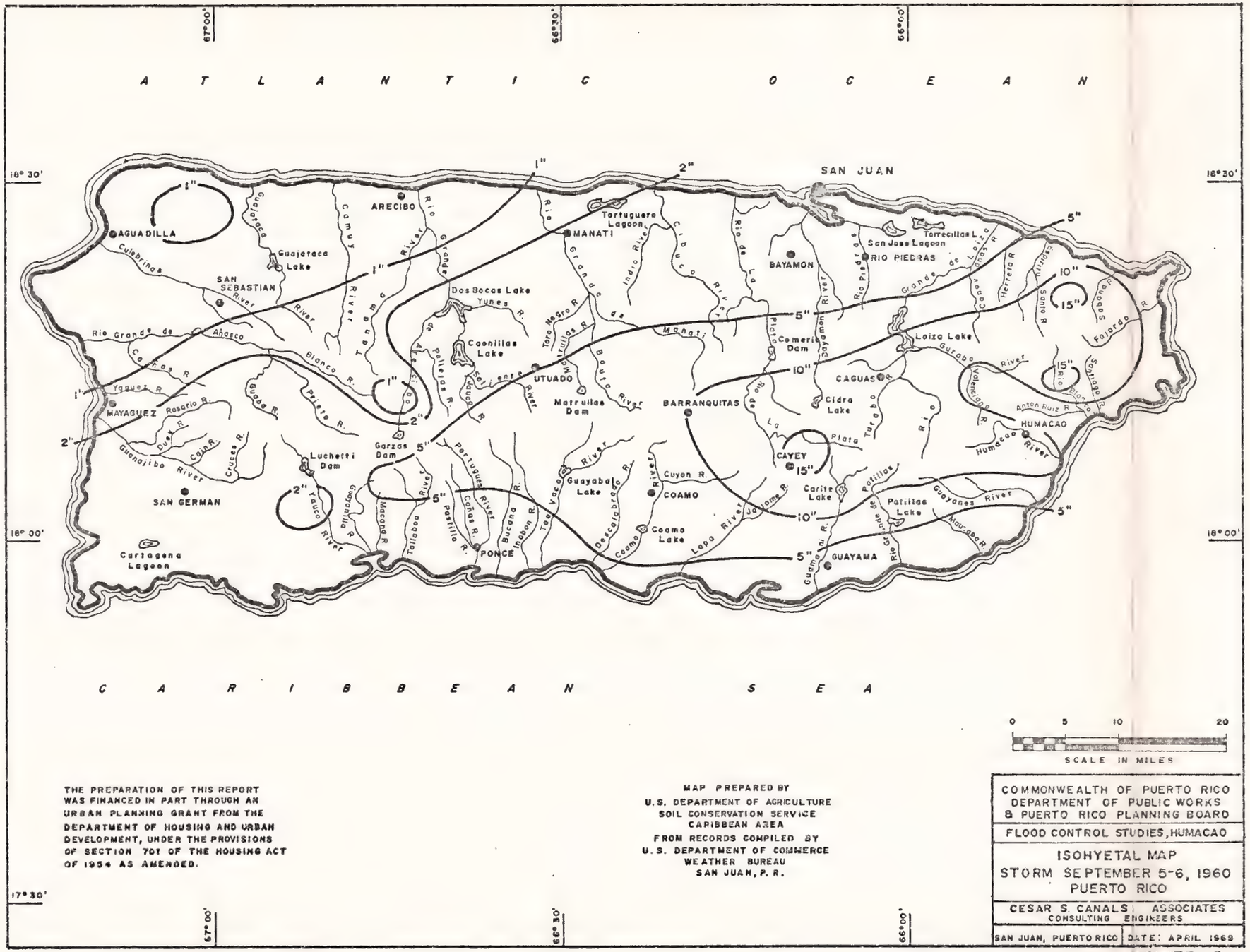
COMMONWEALTH OF PUERTO RICO
DEPARTMENT OF PUBLIC WORKS
& PUERTO RICO PLANNING BOARD

FLOOD CONTROL STUDIES, HUMACAO

25-YEAR & 50-YEAR RAINFALL IN PUERTO RICO

CESAR S. CANALS ASSOCIATES
CONSULTING ENGINEERS
SAN JUAN, PUERTO RICO | DATE: APRIL 1959



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MAP PREPARED BY
U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
CARIBBEAN AREA
FROM RECORDS COMPILED BY
U.S. DEPARTMENT OF COMMERCE
WEATHER BUREAU
SAN JUAN, P. R.

COMMONWEALTH OF PUERTO RICO
DEPARTMENT OF PUBLIC WORKS
& PUERTO RICO PLANNING BOARD

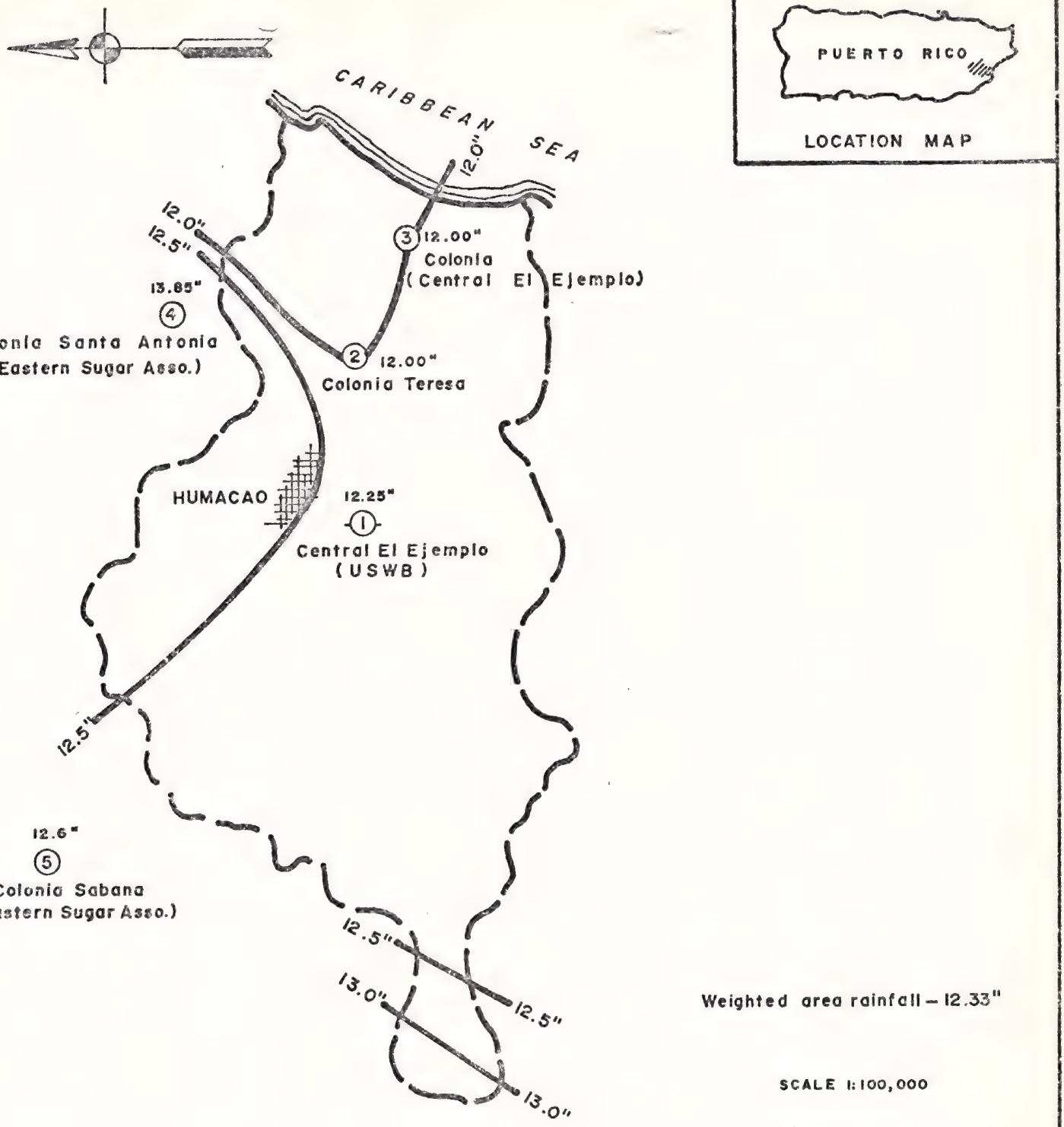
FLOOD CONTROL STUDIES, HUMACAO

ISOHYETAL MAP
STORM SEPTEMBER 5-6, 1960
PUERTO RICO

CESAR S. CANALS & ASSOCIATES
CONSULTING ENGINEERS

SAN JUAN, PUERTO RICO | DATE: APRIL 1962

PLATE 5



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COMMONWEALTH OF PUERTO RICO
DEPARTMENT OF PUBLIC WORKS
& PUERTO RICO PLANNING BOARD

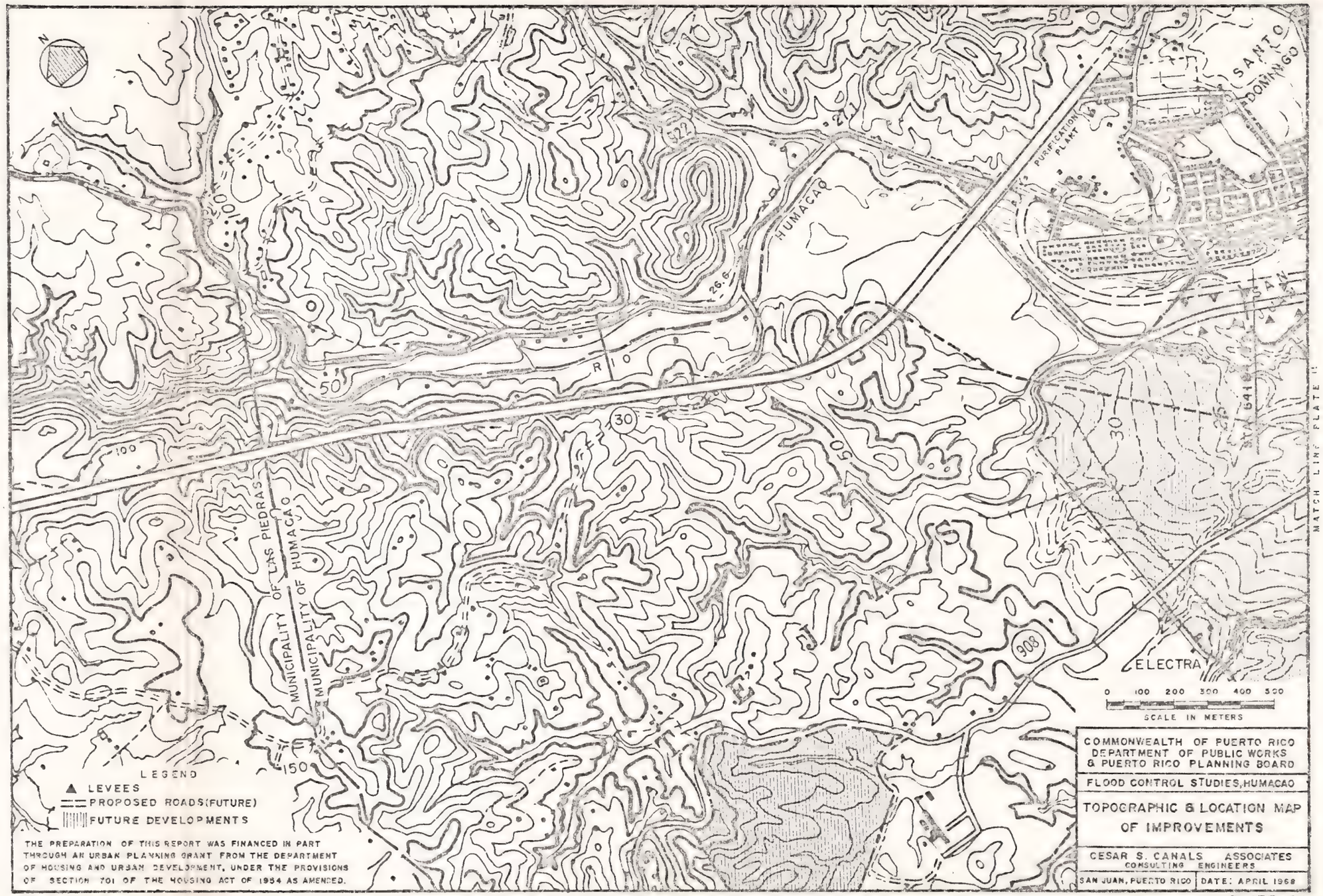
FLOOD CONTROL STUDIES, HUMACAO

ISOHYETAL MAP
STORM SEPTEMBER 5-6, 1960
HUMACAO RIVER WATERSHED

CESAR S. CANALS ASSOCIATES
CONSULTING ENGINEERS

SAN JUAN, PUERTO RICO | DATE: APRIL 1969

PLATE 6



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COMMONWEALTH OF PUERTO RICO
DEPARTMENT OF PUBLIC WORKS
& PUERTO RICO PLANNING BOARD

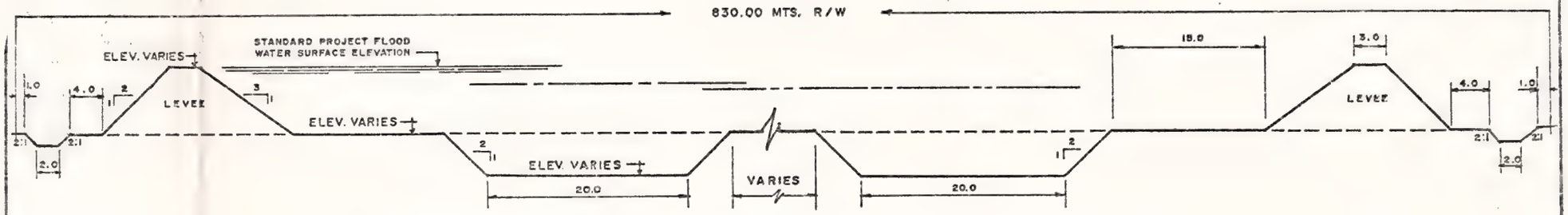
FLOOD CONTROL STUDIES, HUMACAO

TOPOGRAPHIC & LOCATION MAP OF IMPROVEMENTS

CESAR S. CANALS ASSOCIATES
CONSULTING ENGINEERS

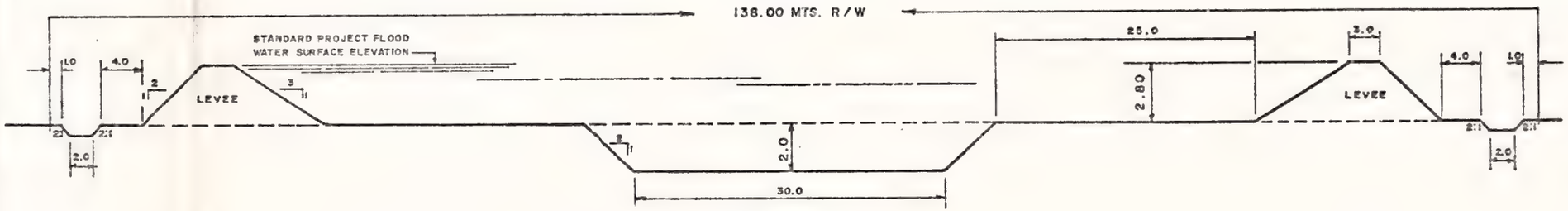
SAN JUAN, PUERTO RICO | DATE: APRIL 1968

PLATE 20



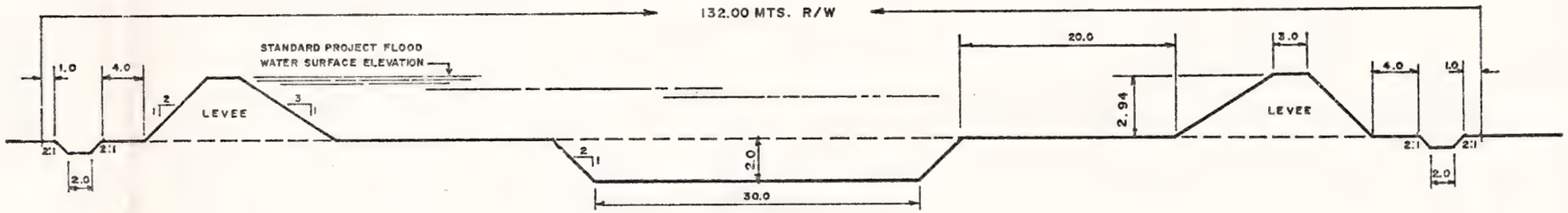
FROM STA. 0+00 TO STA. 17+12

(PLAN "B")



STATION 2+80.00

(PLAN "A")



STATION 17+12.00

(PLANS "A" & "B")

ALL DISTANCES AND MEASUREMENTS SHOWN IN METERS

FOR LOCATION OF STATIONS SEE INDEX MAP (PLATE 17)

THE PREPARATION OF THIS REPORT WAS FINANCED IN PART THROUGH AN URBAN PLANNING GRANT FROM THE DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT, UNDER THE PROVISIONS OF SECTION 701 OF THE HOUSING ACT OF 1954 AS AMENDED.

LEGEND:

1960 (SEPT. 6) FLOOD ———— — ————

INTERMEDIATE REGIONAL FLOOD ———— — ————

COMMONWEALTH OF PUERTO RICO
DEPARTMENT OF PUBLIC WORKS
& PUERTO RICO PLANNING BOARD

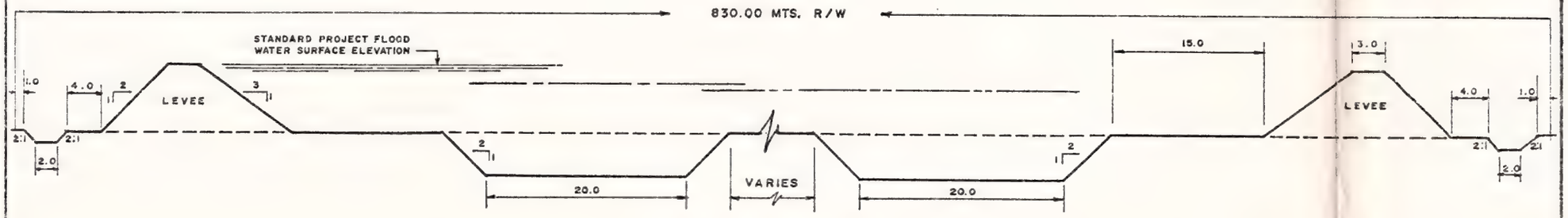
FLOOD CONTROL STUDIES, HUMACAO

SECTIONS OF IMPROVED CHANNEL

CESAR S. CANALS ASSOCIATES
CONSULTING ENGINEERS

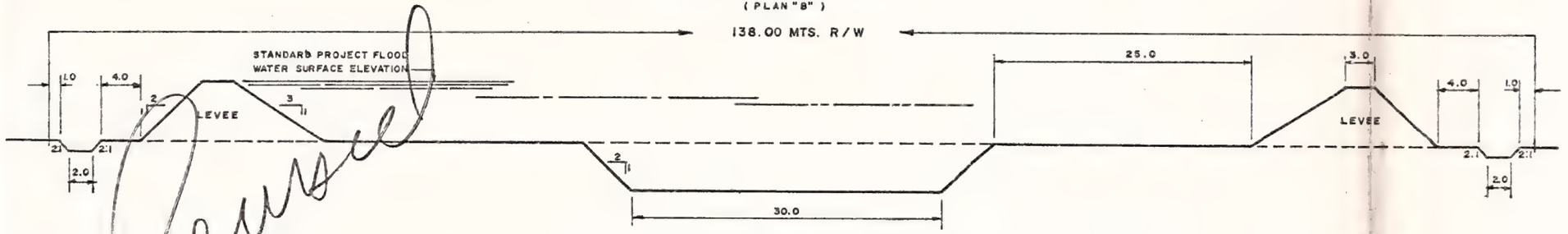
SAN JUAN, PUERTO RICO | DATE APRIL 1969

PLATE 21



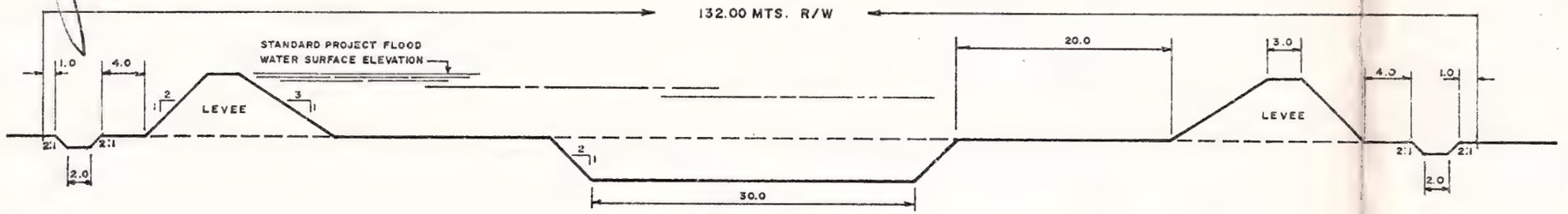
FROM STA. 0+00 TO STA. 17+12

(PLAN "B")



STATION 2+80.00

(PLAN "A")



STATION 17+12.00

(PLANS "A" & "B")

ALL DISTANCES AND MEASUREMENTS SHOWN IN METERS

FOR LOCATION OF STATIONS SEE INDEX MAP (PLATE 17)

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LEGEND:

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INTERMEDIATE REGIONAL FLOOD ———— — — ————

COMMONWEALTH OF PUERTO RICO
DEPARTMENT OF PUBLIC WORKS
& PUERTO RICO PLANNING BOARD

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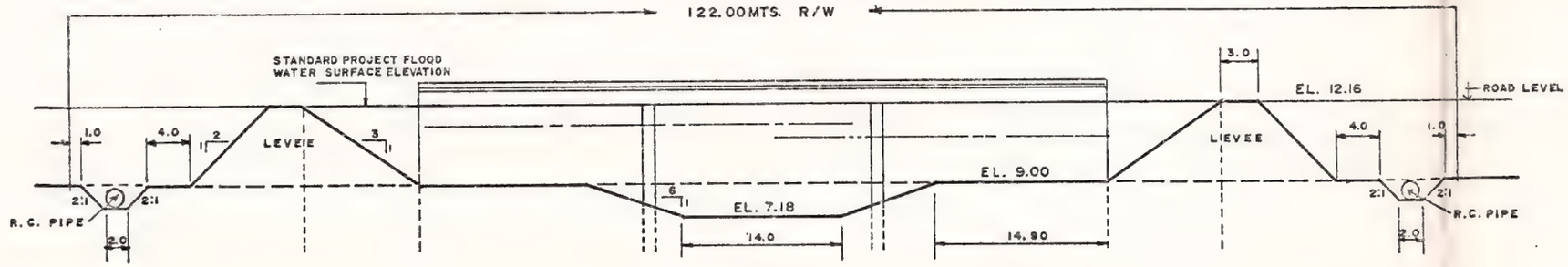
SECTIONS OF IMPROVED CHANNEL

CESAR S. CANALS ASSOCIATES
CONSULTING ENGINEERS

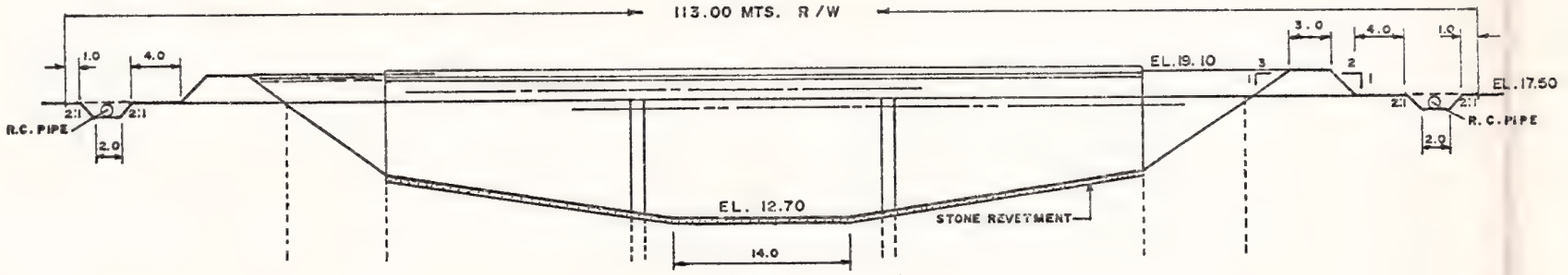
SAN JUAN, PUERTO RICO | DATE. APRIL 1969

PLATE 21



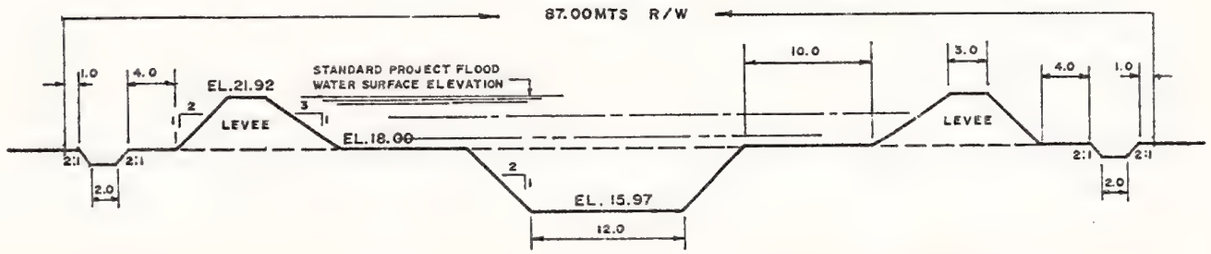
STATION 44+21.71

(PLANS "A" & "B")



STATION 56+89.12

(PLANS "A" & "B")



STATION 64+94.92

(PLANS "A" & "B")

LEGEND

1960 (SEPT. 6) FLOOD ——— — ———

INTERMEDIATE REGIONAL FLOOD ——— — — ———

ALL DISTANCES AND MEASUREMENTS SHOWN IN METERS

FOR LOCATION OF STATIONS SEE INDEX MAP (PLATE 17)

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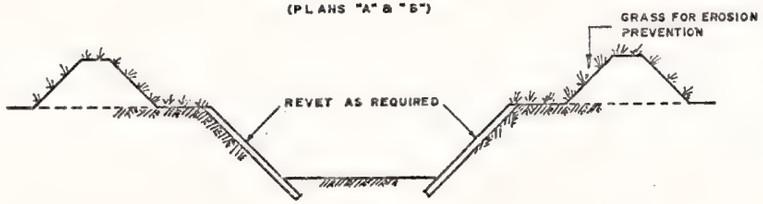


TYPICAL SECTION

COMMONWEALTH OF PUERTO RICO
DEPARTMENT OF PUBLIC WORKS
& PUERTO RICO PLANNING BOARD

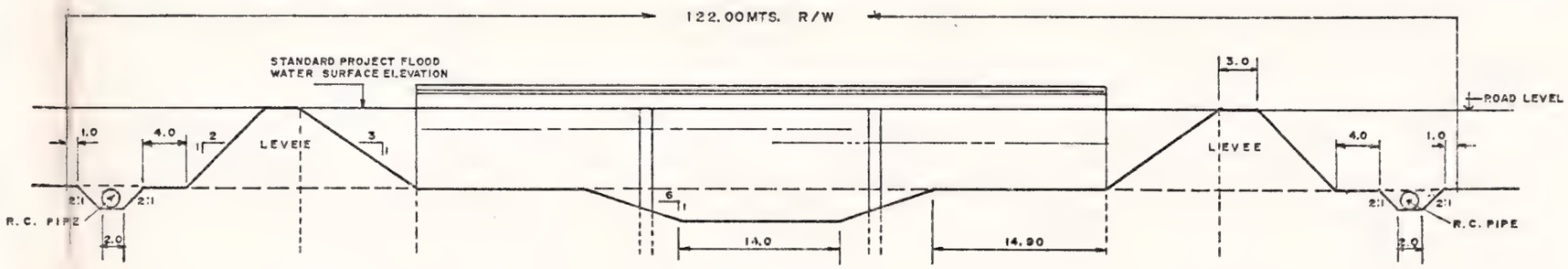
FLOOD CONTROL STUDIES, HUMACAO

SECTIONS OF IMPROVED CHANNEL

CESAR S. CANALS ASSOCIATES
CONSULTING ENGINEERS

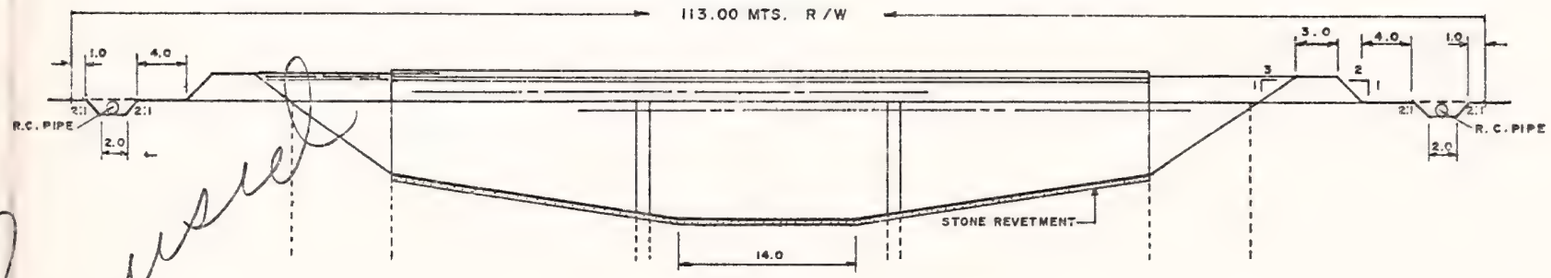
SAN JUAN, PUERTO RICO | DATE: APRIL 1969

PLATE 22



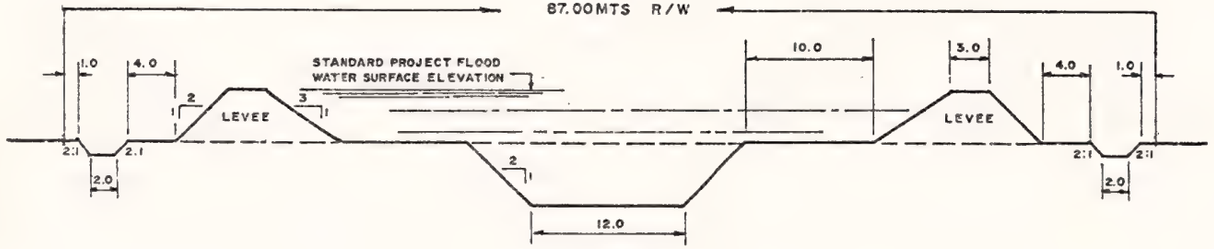
STATION 44+21.71

(PLANS "A" & "B")



STATION 56+89.12

(PLANS "A" & "B")



STATION 64+94.92

(PLANS "A" & "B")

LEGEND

1960 (SEPT. 6) FLOOD ——— — ———

INTERMEDIATE REGIONAL FLOOD ——— — ———

ALL DISTANCES AND MEASUREMENTS SHOWN IN METERS

FOR LOCATION OF STATIONS SEE INDEX MAP (PLATE 17)

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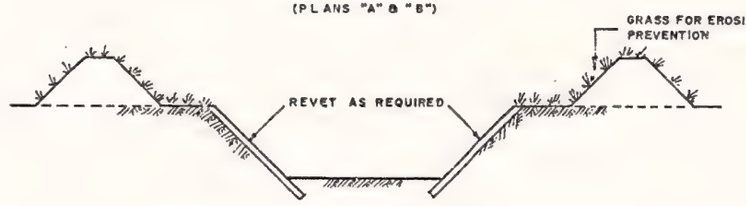


TYPICAL SECTION

COMMONWEALTH OF PUERTO RICO
DEPARTMENT OF PUBLIC WORKS
& PUERTO RICO PLANNING BOARD

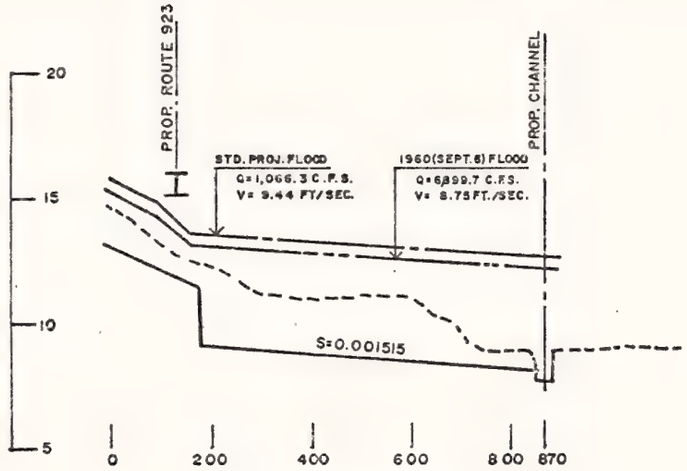
FLOOD CONTROL STUDIES, HUMACAO

SECTIONS OF IMPROVED CHANNEL

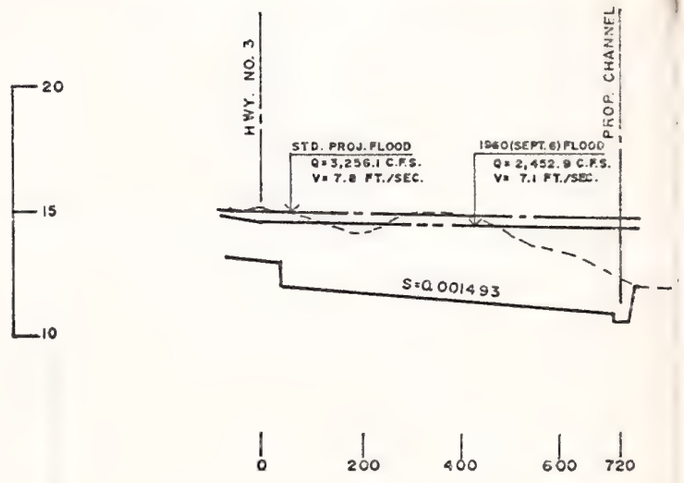
CESAR S. CANALS ASSOCIATES
CONSULTING ENGINEERS

SAN JUAN, PUERTO RICO | DATE: APRIL 1969

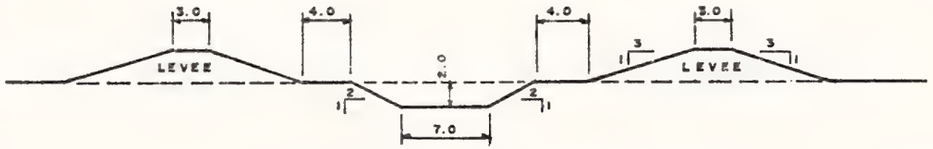
PLATE 22



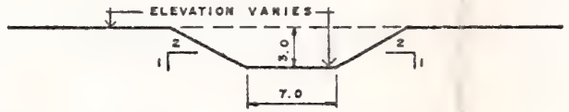
PROFILE-CATAÑO CREEK



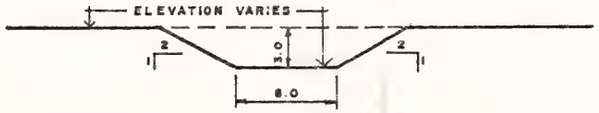
PROFILE-MABU CREEK



TYPICAL SECTION-CATAÑO CREEK



TYPICAL SECTION-MABU CREEK



TYPICAL SECTION-MARIANA CREEK

ALL DISTANCES AND MEASUREMENTS SHOWN IN METERS

THE PRESENTATION OF THIS REPORT WAS FINANCED IN PART THROUGH AN URBAN PLANNING GRANT FROM THE DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT, UNDER THE PROVISIONS OF SECTION 701 OF THE HOUSING ACT OF 1954 AS AMMENDED.

COMMONWEALTH OF PUERTO RICO
DEPARTMENT OF PUBLIC WORKS
& PUERTO RICO PLANNING BOARD

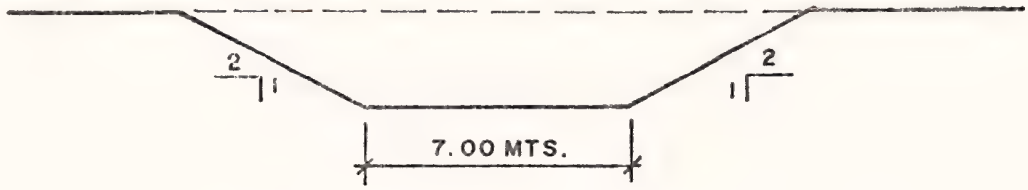
FLOOD CONTROL STUDIES, HUMACAO

PROFILES AND SECTIONS OF IMPROVED CHANNELS

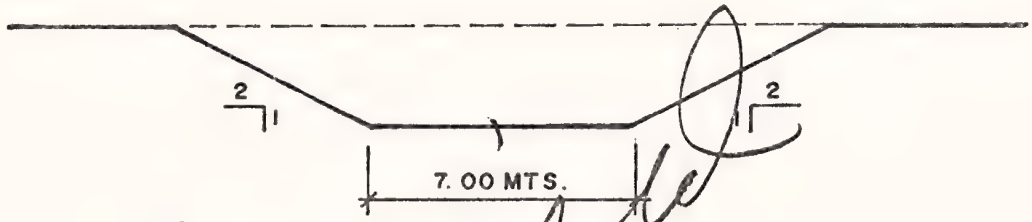
CESAR S. CANALS ASSOCIATES
CONSULTING ENGINEERS

SAN JUAN, PUERTO RICO | DATE: APRIL 1969

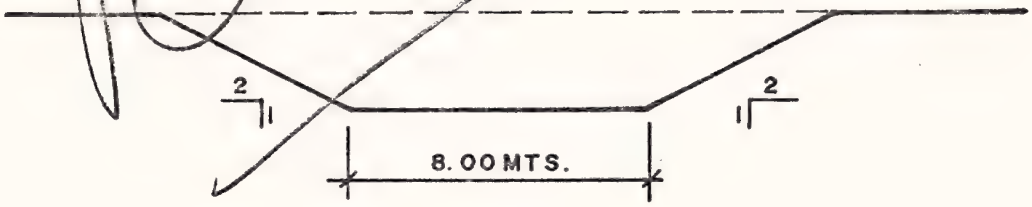
PLATE 23



TYPICAL SECTION-CATAÑO CREEK



TYPICAL SECTION-MABU CREEK



TYPICAL SECTION-MARIANA CREEK

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COMMONWEALTH OF PUERTO RICO
DEPARTMENT OF PUBLIC WORKS
& PUERTO RICO PLANNING BOARD

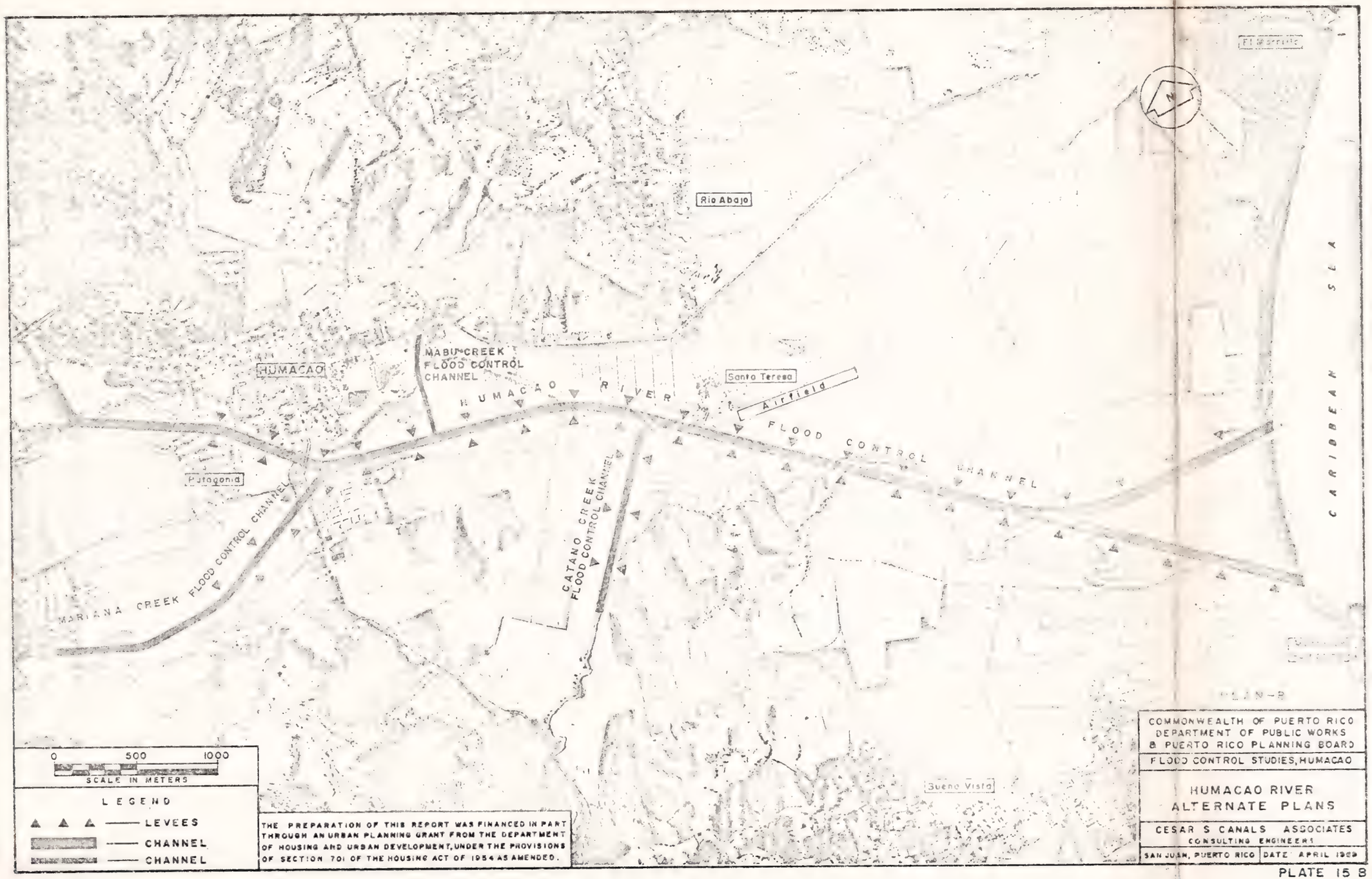
FLOOD CONTROL STUDIES, HUMACAO

SECTIONS OF IMPROVED CHANNELS

CESAR S. CANALS ASSOCIATES
CONSULTING ENGINEERS
SAN JUAN, PUERTO RICO | DATE: APRIL 1969


El Morillo
Río Abajo
HUMACAO
MABU CREEK FLOOD CONTROL CHANNEL
HUMACAO RIVER
Santa Teresa
Airfield
FLOOD CONTROL CHANNEL
TWIN JETTIES
CLOSE TO 1.0m M.S.L.
CARIBBEAN SEA
Pelogonia
HUMACAO CREEK FLOOD CONTROL CHANNEL
CATAÑO CREEK FLOOD CONTROL CHANNEL
Bueno Vista
N
0 500 1000
SCALE IN METERS
LEGEND
LEVEES
CHANNEL
CHANNEL
THE PREPARATION OF THIS REPORT WAS FINANCED IN PART THROUGH AN URBAN PLANNING GRANT FROM THE DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT, UNDER THE PROVISIONS OF SECTION 701 OF THE HOUSING ACT OF 1954 AS AMENDED.
COMMONWEALTH OF PUERTO RICO
DEPARTMENT OF PUBLIC WORKS
& PUERTO RICO PLANNING BOARD
FLOOD CONTROL STUDIES, HUMACAO
HUMACAO RIVER
ALTERNATE PLANS
CESAR S. CANALS ASSOCIATES
CONSULTING ENGINEERS
SAN JUAN, PUERTO RICO
DATE: APRIL 1965

PLATE 15 A



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COMMONWEALTH OF PUERTO RICO
DEPARTMENT OF PUBLIC WORKS
& PUERTO RICO PLANNING BOARD

FLOOD CONTROL STUDIES, HUMACAO

HUMACAO RIVER ALTERNATE PLANS

CESAR S CANALS ASSOCIATES
CONSULTING ENGINEERS

SAN JUAN, PUERTO RICO | DATE APRIL 1969

PLATE 15 B

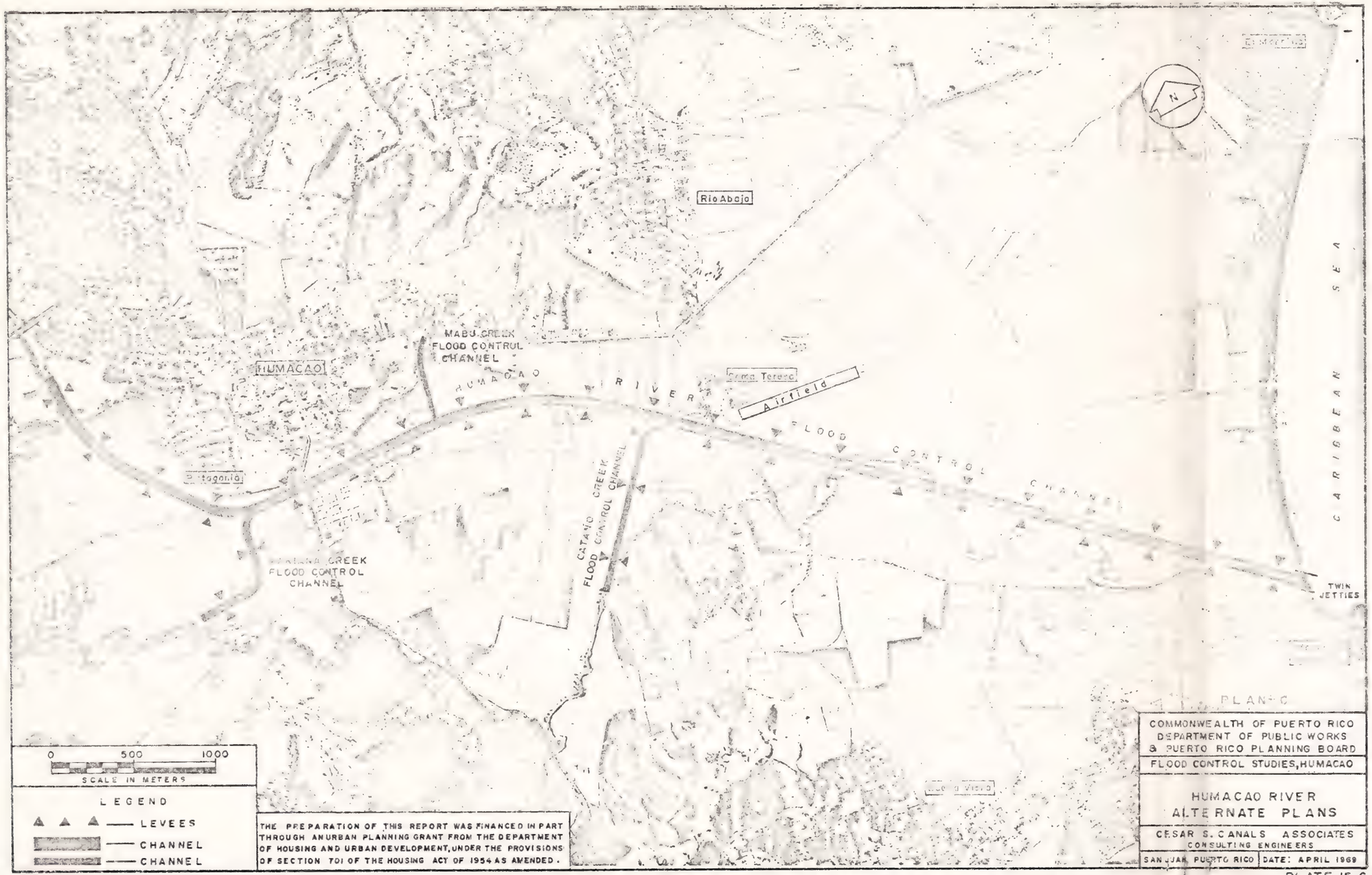
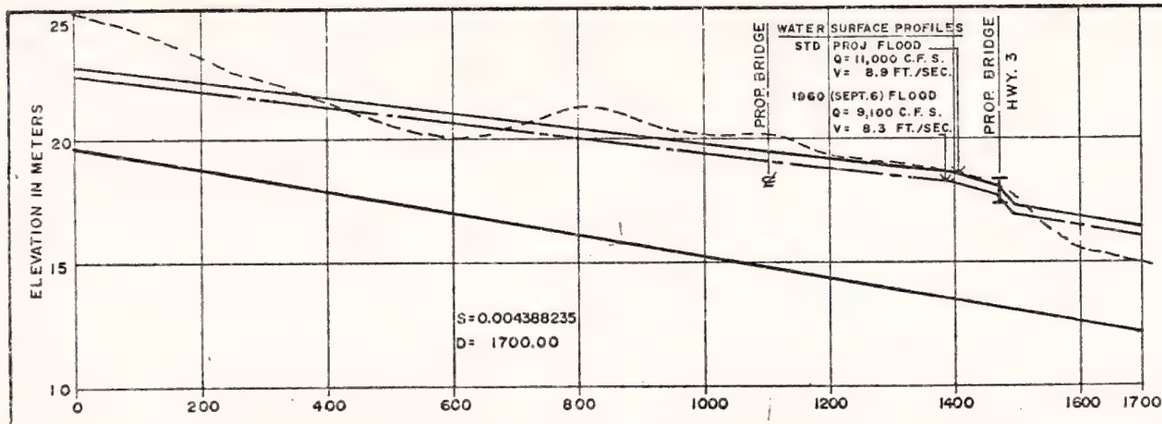
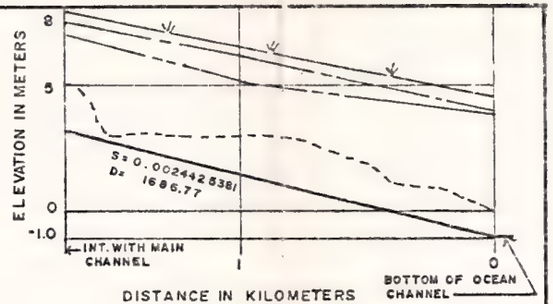

Rio Abajo
MABU CREEK FLOOD CONTROL CHANNEL
HUMACAO
HUMACAO RIVER
Cerro Terero
Airfield
FLOOD CONTROL CHANNEL
Patagonia
CATANO CREEK FLOOD CONTROL CHANNEL
CARIBBEAN SEA
TWIN JETTIES
0 500 1000
SCALE IN METERS
LEGEND
LEVEES
CHANNEL
CHANNEL
THE PREPARATION OF THIS REPORT WAS FINANCED IN PART THROUGH AN URBAN PLANNING GRANT FROM THE DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT, UNDER THE PROVISIONS OF SECTION 701 OF THE HOUSING ACT OF 1954 AS AMENDED.
PLAN C
COMMONWEALTH OF PUERTO RICO
DEPARTMENT OF PUBLIC WORKS
& PUERTO RICO PLANNING BOARD
FLOOD CONTROL STUDIES, HUMACAO
HUMACAO RIVER
ALTERNATE PLANS
CESAR S. CANALS ASSOCIATES
CONSULTING ENGINEERS
SAN JUAN, PUERTO RICO
DATE: APRIL 1969

PLATE 15 C

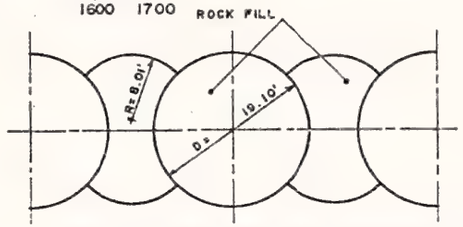


MARIANA CREEK

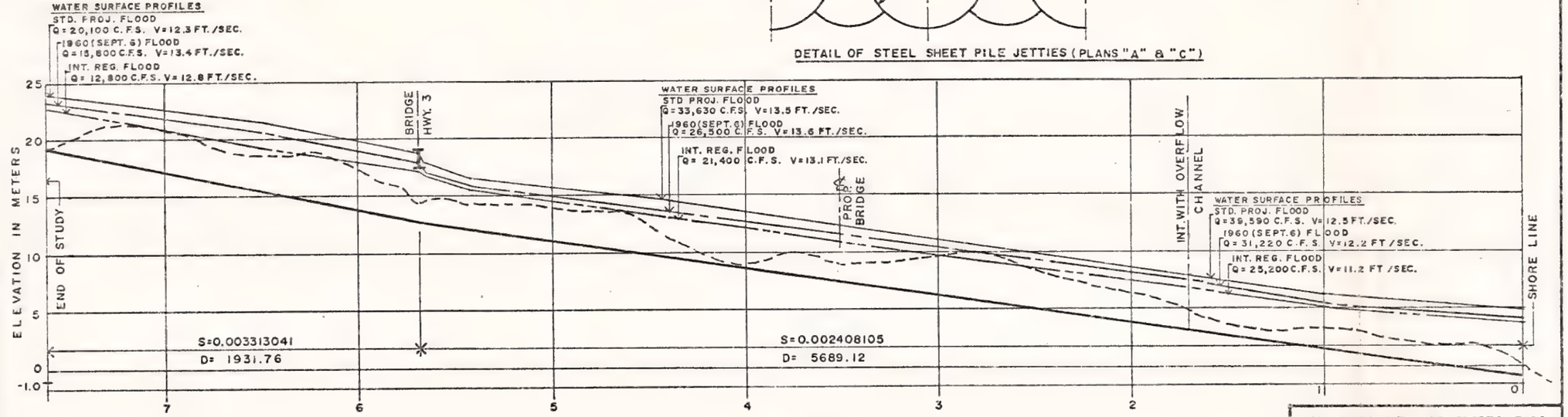


OVERFLOW CHANNEL

PLAN-B



DETAIL OF STEEL SHEET PILE JETTIES (PLANS "A" & "C")



MAIN CHANNEL

PLAN-B

LEGEND

- BOTTOM OF CHANNEL
- EXISTING GROUND
- STANDARD PROJECT FLOOD
- TOP OF LEVEES & S.P.F.
- 1960 (SEPT. 6) FLOOD
- INTERMEDIATE REGIONAL FLOOD
- BRIDGE
  - FLOOR
  - LOW BEAM

COMMONWEALTH OF PUERTO RICO
DEPARTMENT OF PUBLIC WORKS
& PUERTO RICO PLANNING BOARD

FLOOD CONTROL STUDIES, HUMACAO

PROFILES AND DETAIL

CESAR S. CANALS ASSOCIATES
CONSULTING ENGINEERS

SAN JUAN, PUERTO RICO | DATE: APRIL 1965

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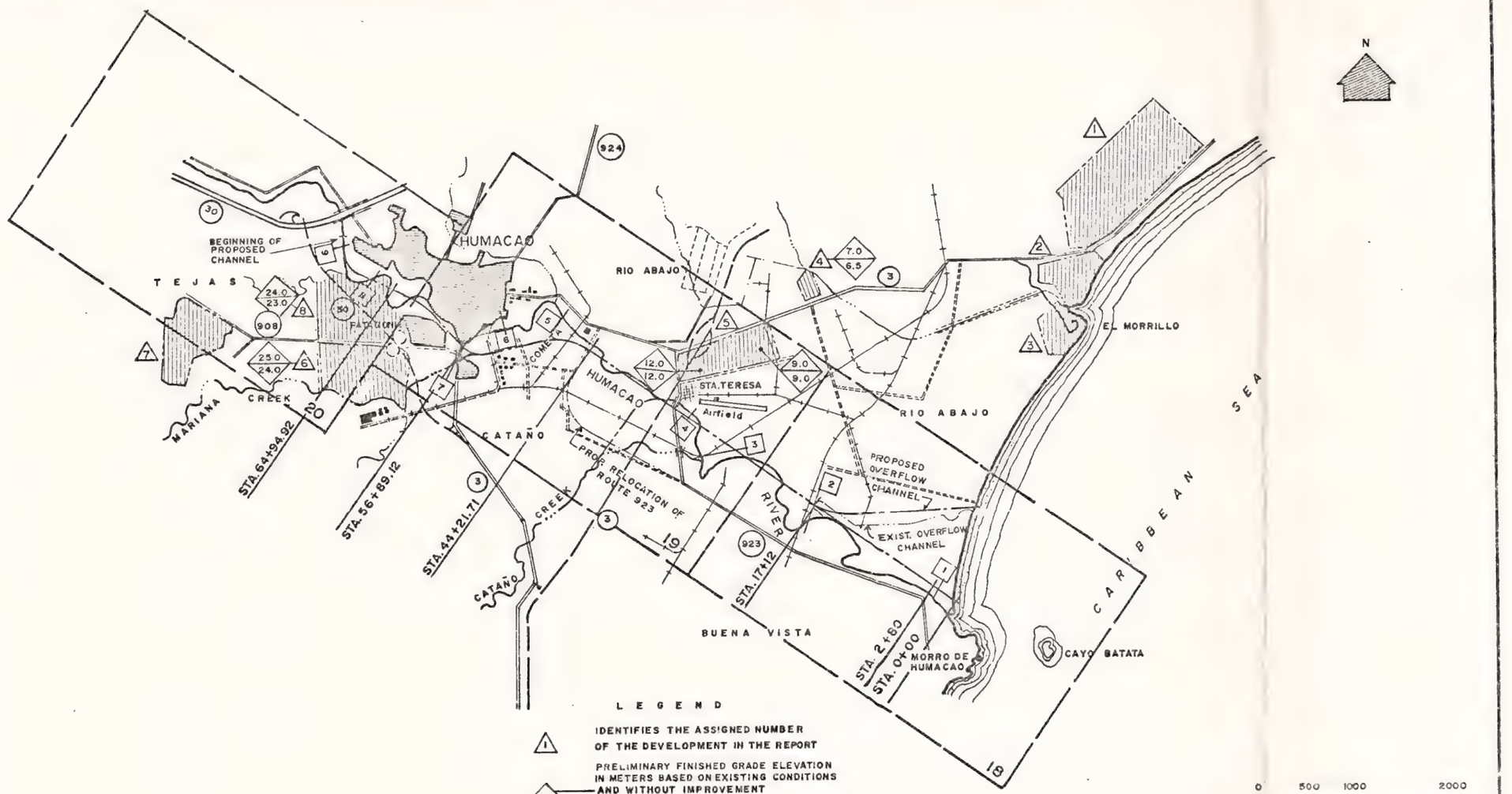
PLATE 16



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COMMONWEALTH OF PUERTO RICO
DEPARTMENT OF PUBLIC WORKS
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FLOOD CONTROL STUDIES, HUMACAO

INDEX MAP

CESAR S. CANALS ASSOCIATES
CONSULTING ENGINEERS
SAN JUAN, PUERTO RICO

DATE: APRIL 1969

PLATE 17

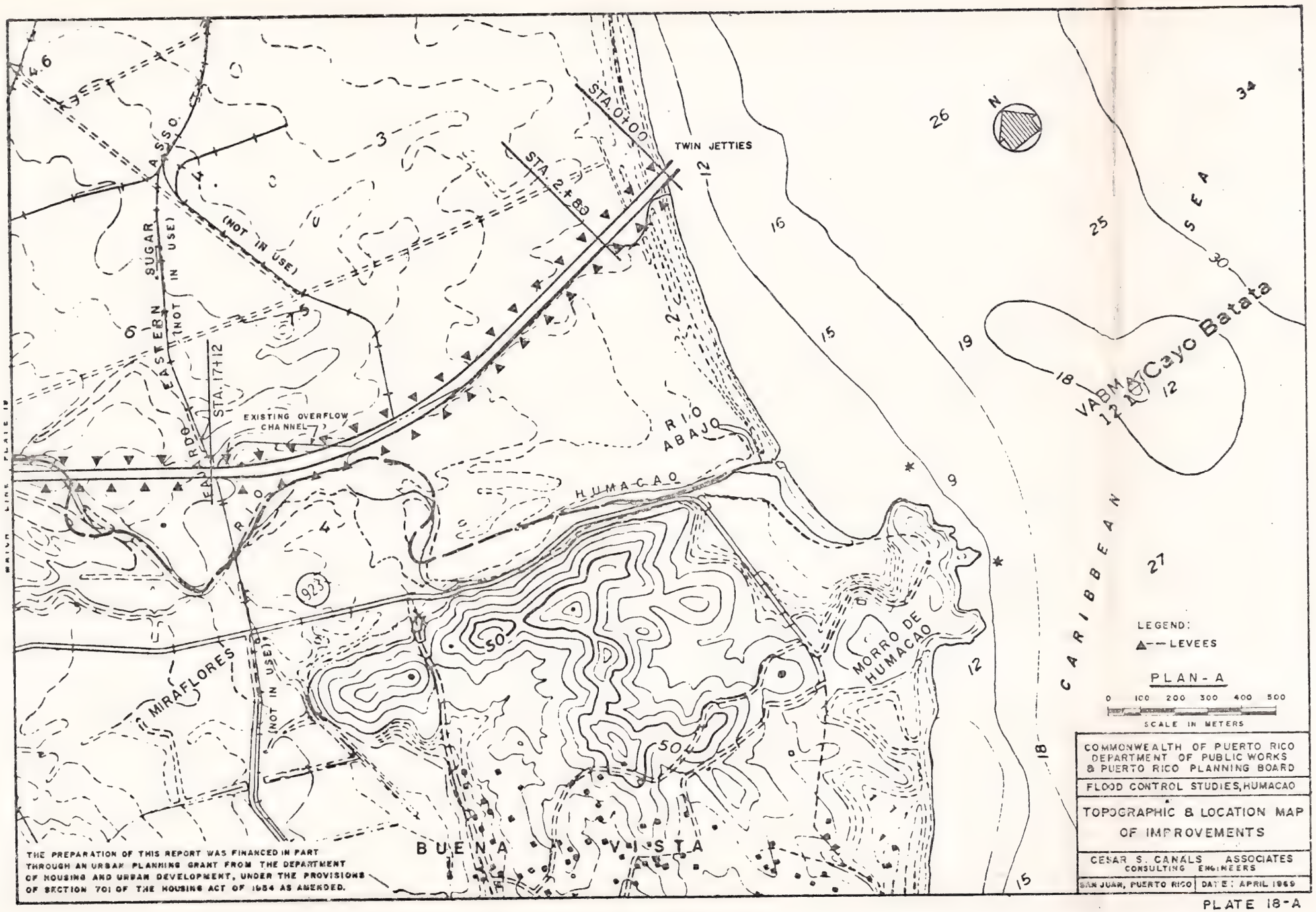

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PLATE 18-A

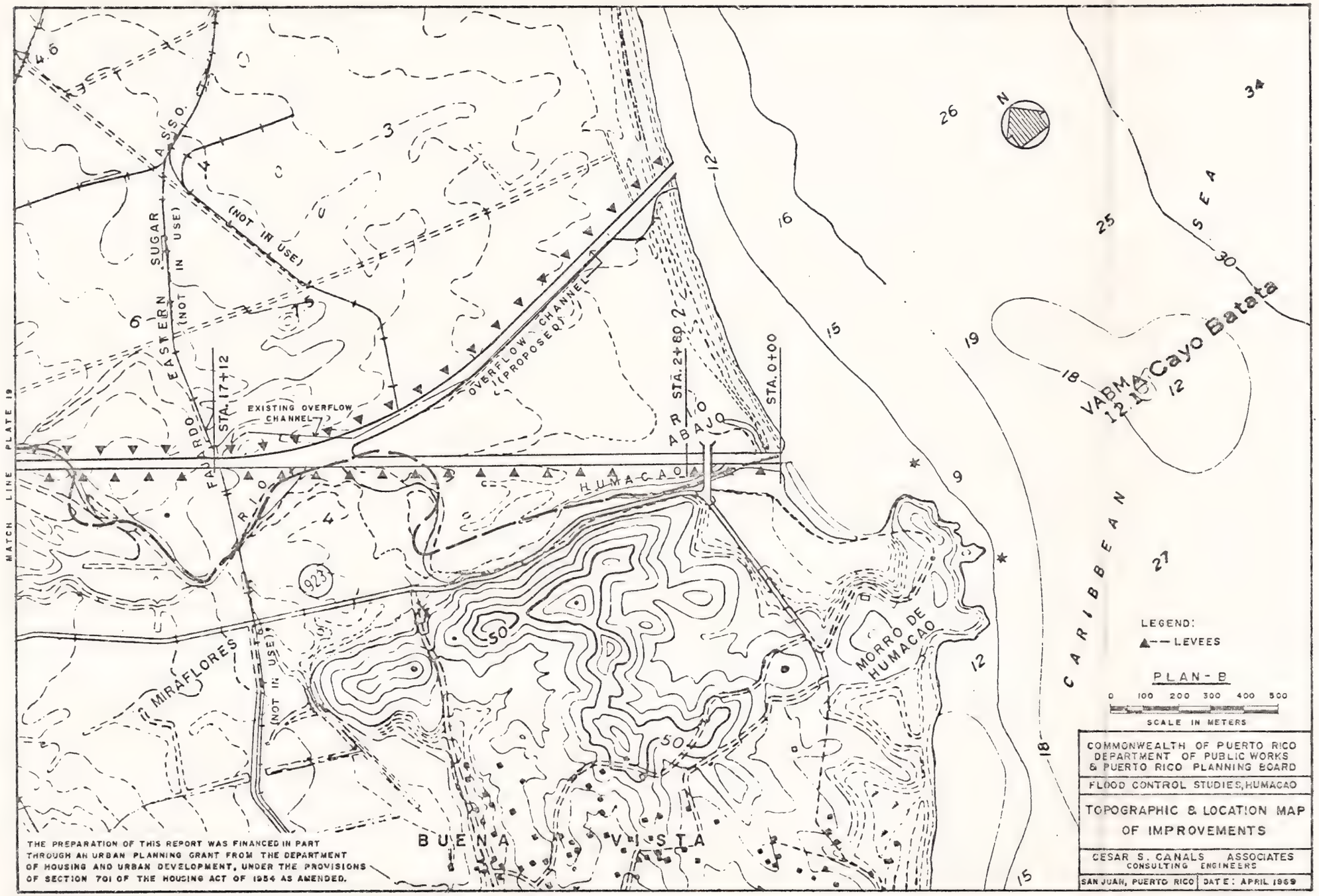

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PLATE 18-B

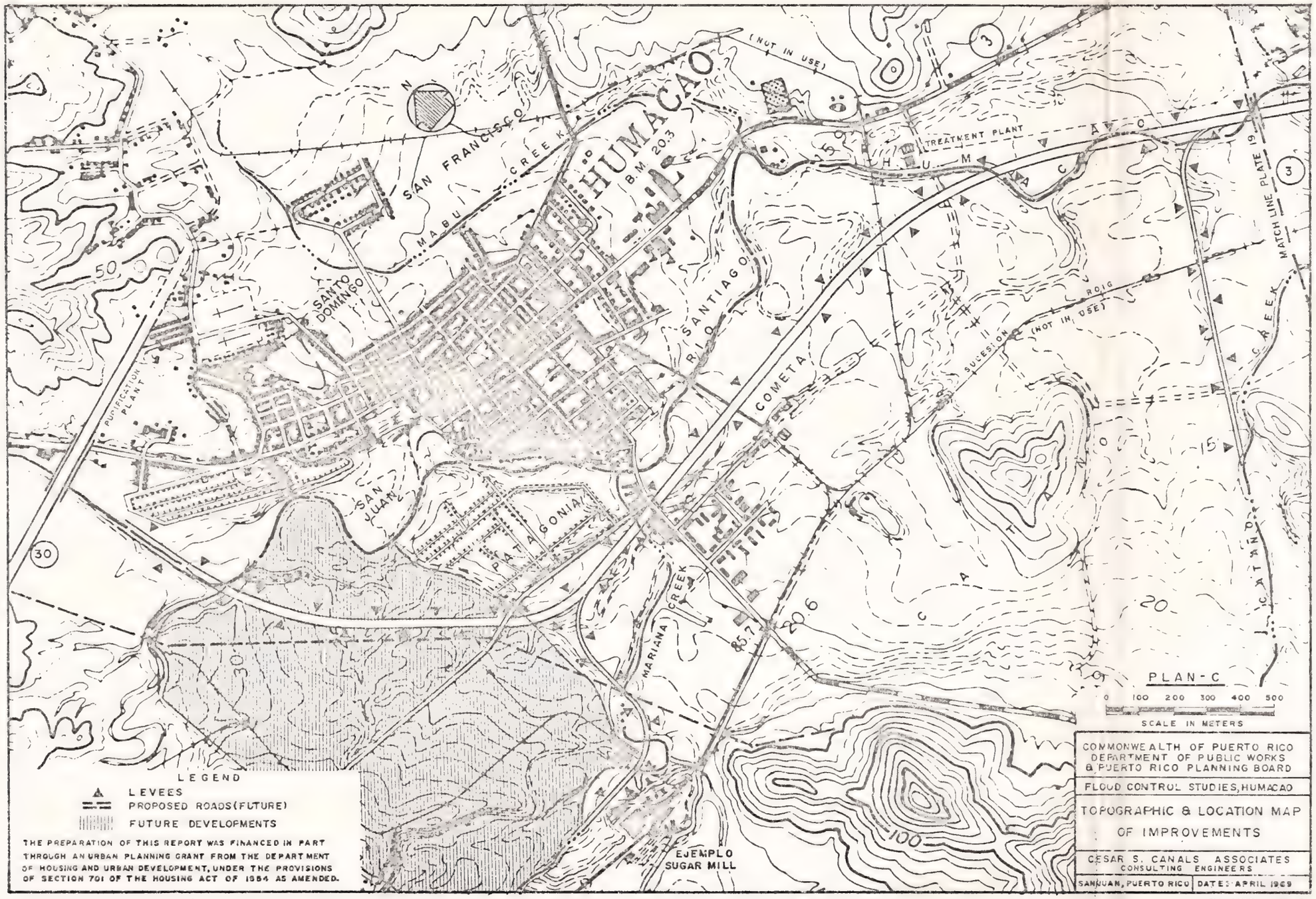

HUMACAO
B.M. 203
SAN FRANCISCO CREEK
MABU CREEK
(NOT IN USE)
TREATMENT PLANT
HUMACAO CREEK
MATCH LINE PLATE 19
SANTO DOMINGO
PURIFICATION PLANT
SAN JUAN
PATAGONIA
SANTIAGO RIO
COMETA
SUCESION ROIG
(NOT IN USE)
ROIG CREEK
MARIANA CREEK
EJEMPLO SUGAR MILL
50
30
20
15
100
206
85.7
PLAN-C
0 100 200 300 400 500
SCALE IN METERS
LEGEND
LEVEES
PROPOSED ROADS (FUTURE)
FUTURE DEVELOPMENTS
THE PREPARATION OF THIS REPORT WAS FINANCED IN PART THROUGH AN URBAN PLANNING GRANT FROM THE DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT, UNDER THE PROVISIONS OF SECTION 701 OF THE HOUSING ACT OF 1954 AS AMENDED.
COMMONWEALTH OF PUERTO RICO
DEPARTMENT OF PUBLIC WORKS
& PUERTO RICO PLANNING BOARD
FLOOD CONTROL STUDIES, HUMACAO
TOPOGRAPHIC & LOCATION MAP OF IMPROVEMENTS
CESAR S. CANALS ASSOCIATES
CONSULTING ENGINEERS
SANJUAN, PUERTO RICO
DATE: APRIL 1969

PLATE 18-C

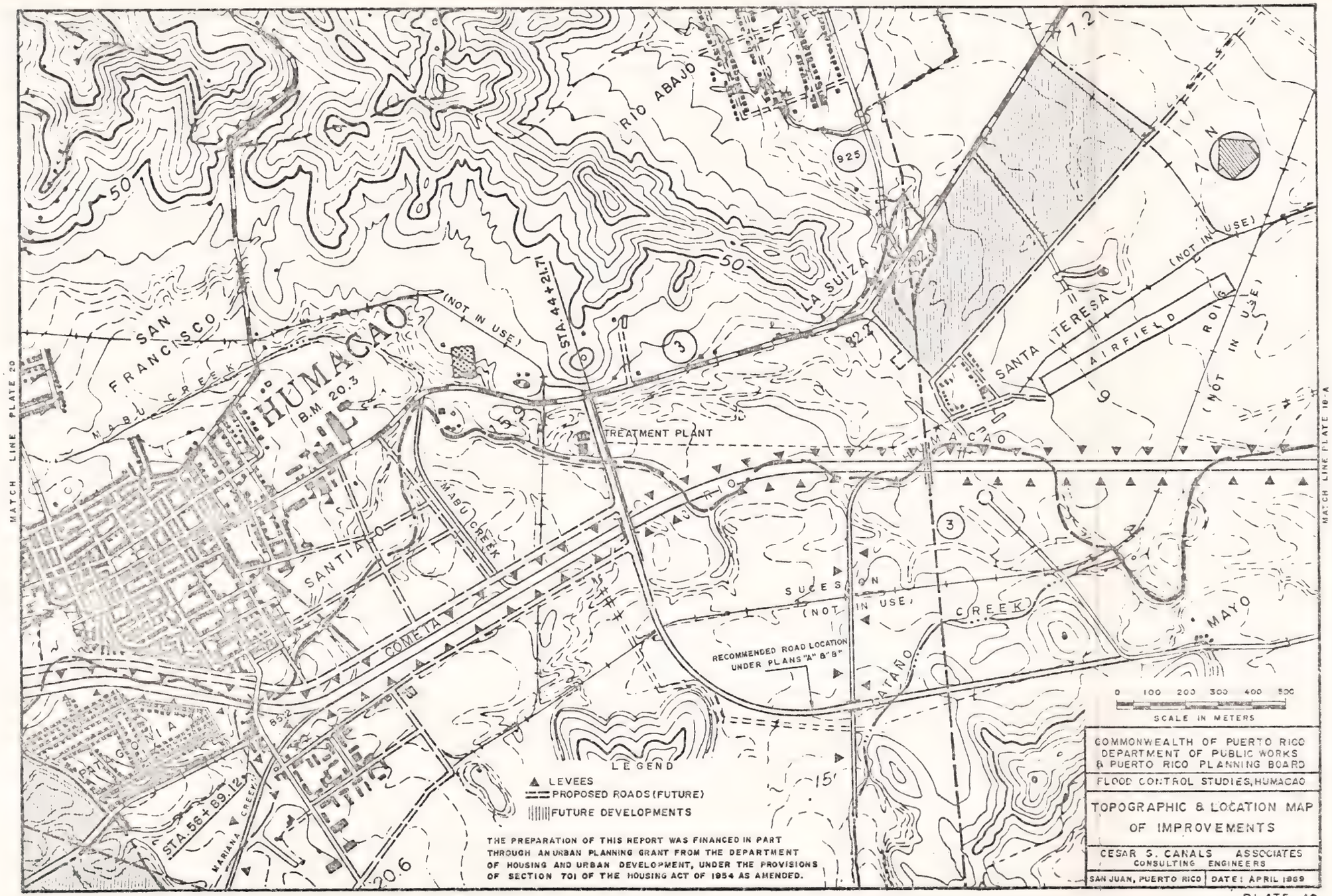
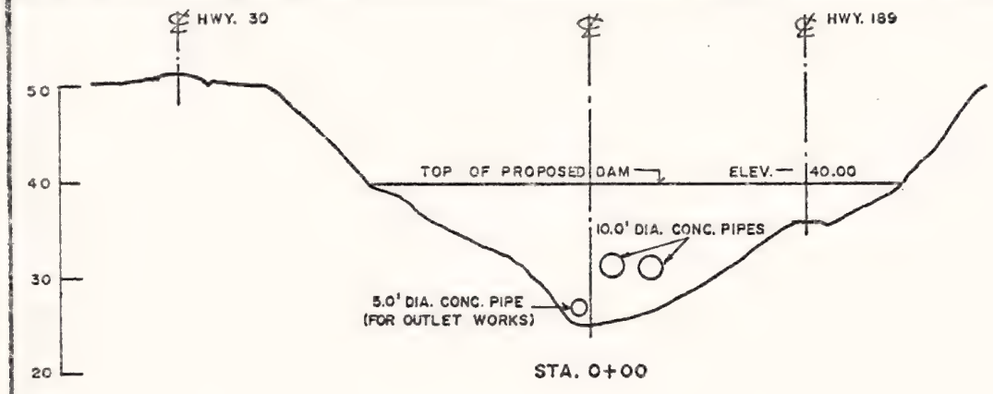
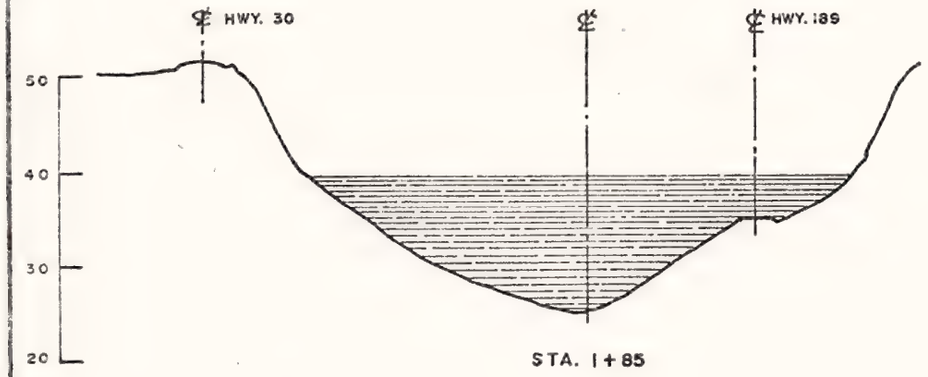

MATCH LINE PLATE 20
MATCH LINE PLATE 18-A
RIO ABAJO
LA SUIZA
SAN FRANCISCO
HUMACAO
B.M. 20.3
MABU CREEK
STA. 44+21.7
(NOT IN USE)
TREATMENT PLANT
SANTIAGO
COMETA
PATAGONIA
STA. 56+89.12
MARIANA CREEK
SANTA TERESA
AIRFIELD
(NOT IN USE)
RIO MACAO
SUCESION CREEK
(NOT IN USE)
RECOMMENDED ROAD LOCATION UNDER PLANS "A" & "B"
ATANO
MAYO
925
50
82
15
20.6
0 100 200 300 400 500
SCALE IN METERS
LEGEND
LEVEES
PROPOSED ROADS (FUTURE)
FUTURE DEVELOPMENTS
THE PREPARATION OF THIS REPORT WAS FINANCED IN PART THROUGH AN URBAN PLANNING GRANT FROM THE DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT, UNDER THE PROVISIONS OF SECTION 701 OF THE HOUSING ACT OF 1954 AS AMENDED.
COMMONWEALTH OF PUERTO RICO
DEPARTMENT OF PUBLIC WORKS
& PUERTO RICO PLANNING BOARD
FLOOD CONTROL STUDIES, HUMACAO
TOPOGRAPHIC & LOCATION MAP OF IMPROVEMENTS
CESAR S. CANALS ASSOCIATES
CONSULTING ENGINEERS
SAN JUAN, PUERTO RICO
DATE: APRIL 1969

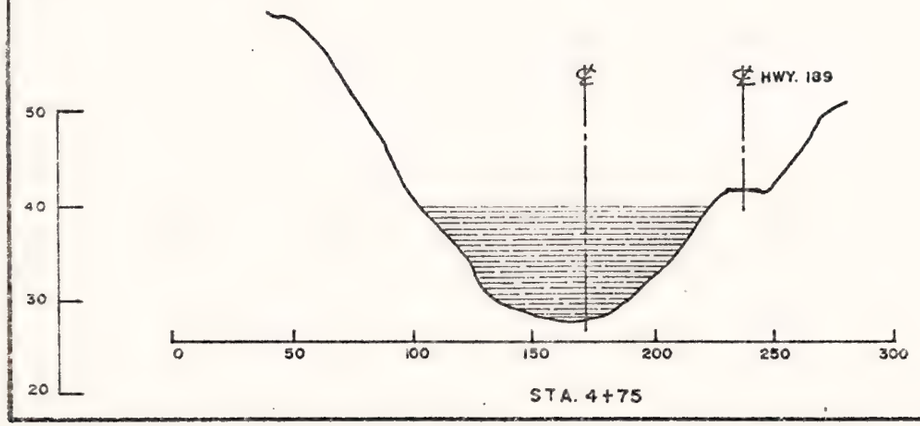
PLATE 19



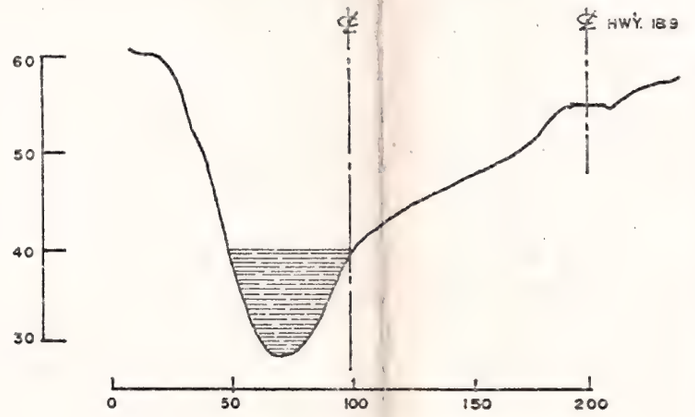
STA. 0+00



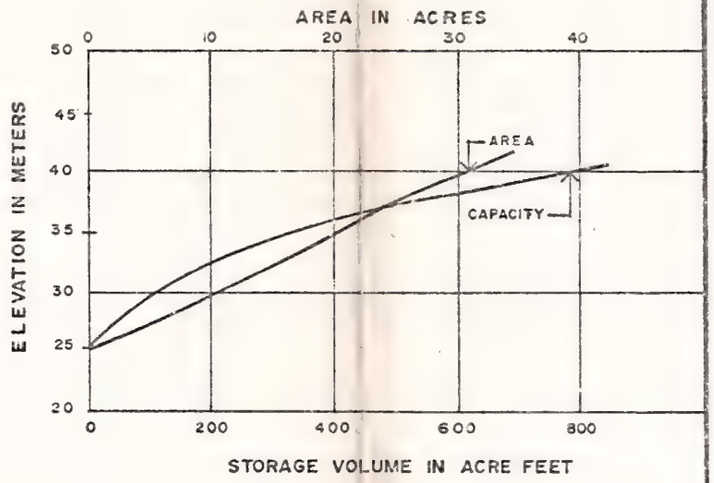
STA. 1+85



STA. 4+75



STA. 7+85



STORAGE VOLUME IN ACRE FEET

NOTES

ALL DISTANCES AND ELEVATIONS IN METERS.

ALL SECTIONS LOOKING UPSTREAM.

THE PREPARATION OF THIS REPORT WAS FINANCED IN PART THROUGH AN URBAN PLANNING GRANT FROM THE DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT, UNDER THE PROVISIONS OF SECTION 701 OF THE HOUSING ACT OF 1954 AS AMENDED.

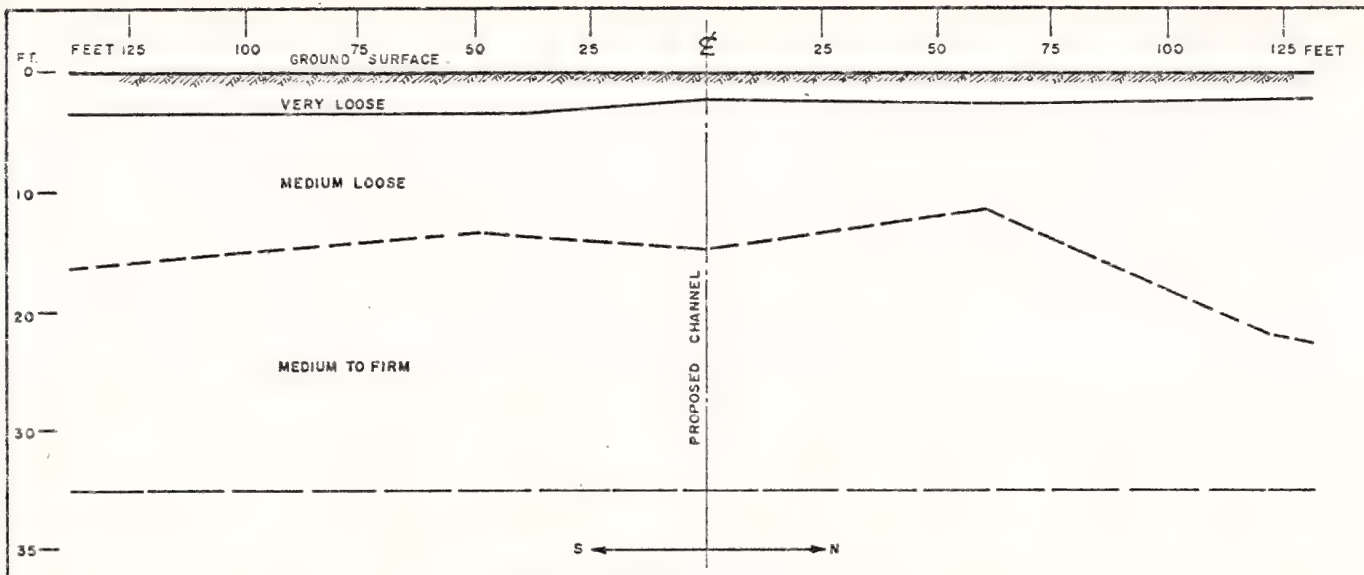
COMMONWEALTH OF PUERTO RICO
DEPARTMENT OF PUBLIC WORKS
& PUERTO RICO PLANNING BOARD

FLOOD CONTROL STUDIES, HUMACAO

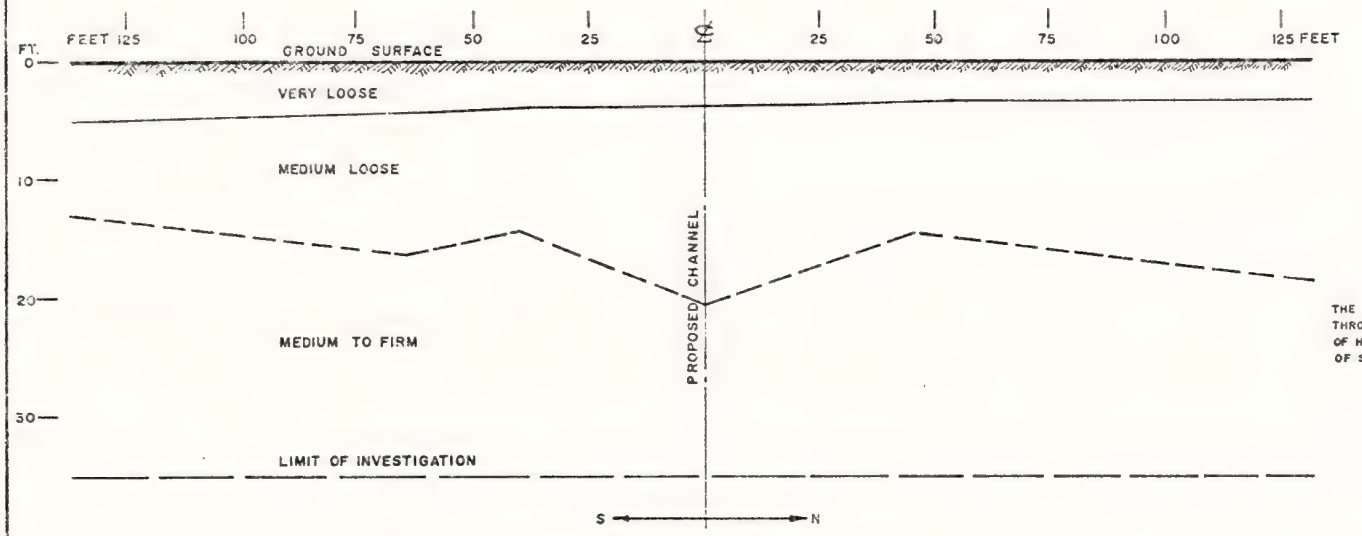
TYPICAL SECTIONS AND AREA-CAPACITY CURVES OF PROPOSED RESERVOIR

CESAR S. CANALS ASSOCIATES
CONSULTING ENGINEERS
SAN JUAN, PUERTO RICO | DATE- APRIL 1969

PLATE 24



PROFILE THROUGH STATION 17+12.00



PROFILE THROUGH STATION 47+20.00

FIELD WORK BY BUSSMAN & ASSOCIATES
CONSULTING ENGINEERS SAN JUAN, P. R.

THE PREPARATION OF THIS REPORT WAS FINANCED IN PART THROUGH AN URBAN PLANNING GRANT FROM THE DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT, UNDER THE PROVISIONS OF SECTION 701 OF THE HOUSING ACT OF 1954 AS AMENDED.

COMMONWEALTH OF PUERTO RICO
DEPARTMENT OF PUBLIC WORKS
& PUERTO RICO PLANNING BOARD

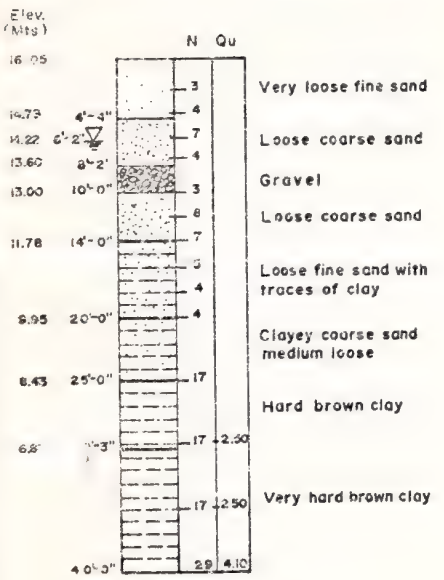
FLOOD CONTROL STUDIES, HUMACAO

SEISMIC PROFILES

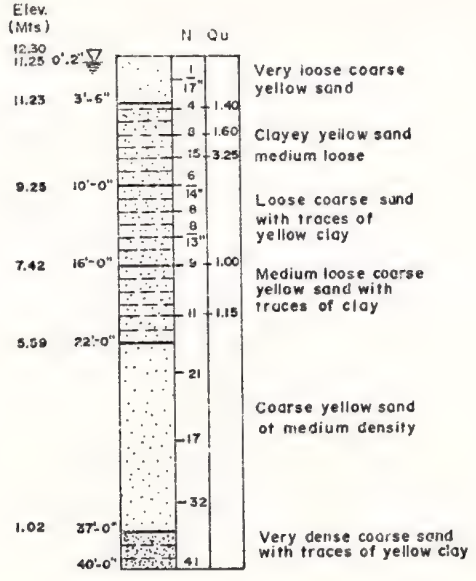
CESAR S. CANALS ASSOCIATES
CONSULTING ENGINEERS

SAN JUAN, PUERTO RICO | DATE: APRIL 1969

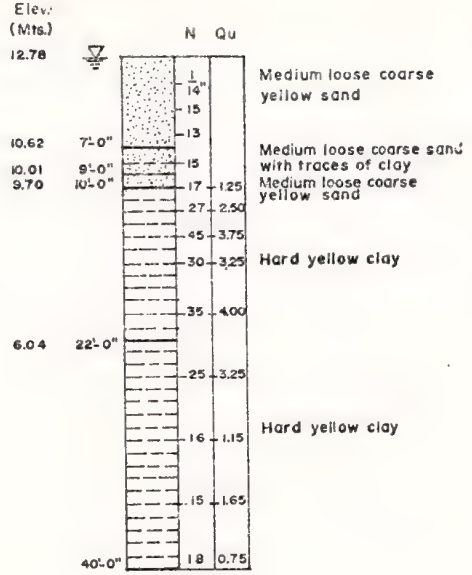
PLATE 7



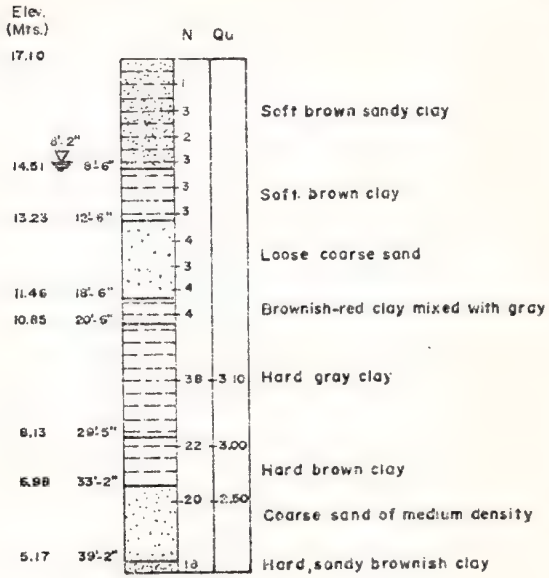
LEFT ABUTMENT



PIER 1



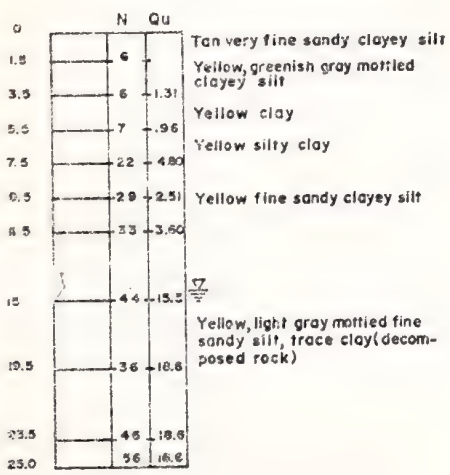
PIER 2



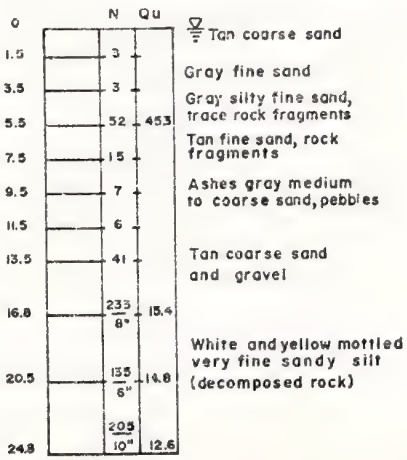
RIGHT ABUTMENT

LEGEND
N — RESISTANCE TO STANDARD PENETRATION
Qu — RESISTANCE TO SIMPLE COMP.
WATER TABLE

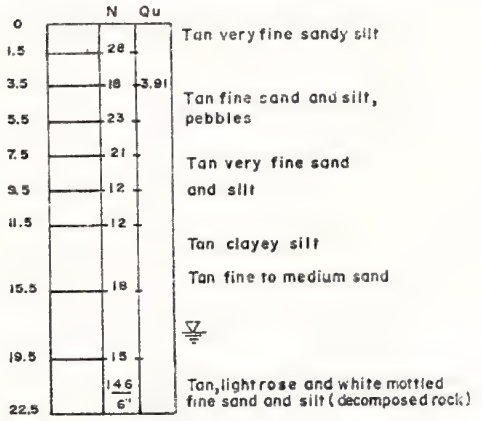
RIVER STATION 56+89.12 LOOKING DOWNSTREAM



LEFT PIER



CENTER PIER



RIGHT PIER

RIVER STATION 76+20.88 LOOKING DOWNSTREAM

DATA OBTAINED FROM RECORDS OF P.R. DEPT. OF PUBLIC WORKS AND PUERTO RICO TESTING SERVICES, INC., SAN JUAN, P.R.

THE PREPARATION OF THIS REPORT WAS FINANCED IN PART THROUGH AN URBAN PLANNING GRANT FROM THE DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT, UNDER THE PROVISIONS OF SECTION 701 OF THE HOUSING ACT OF 1954 AS AMENDED.

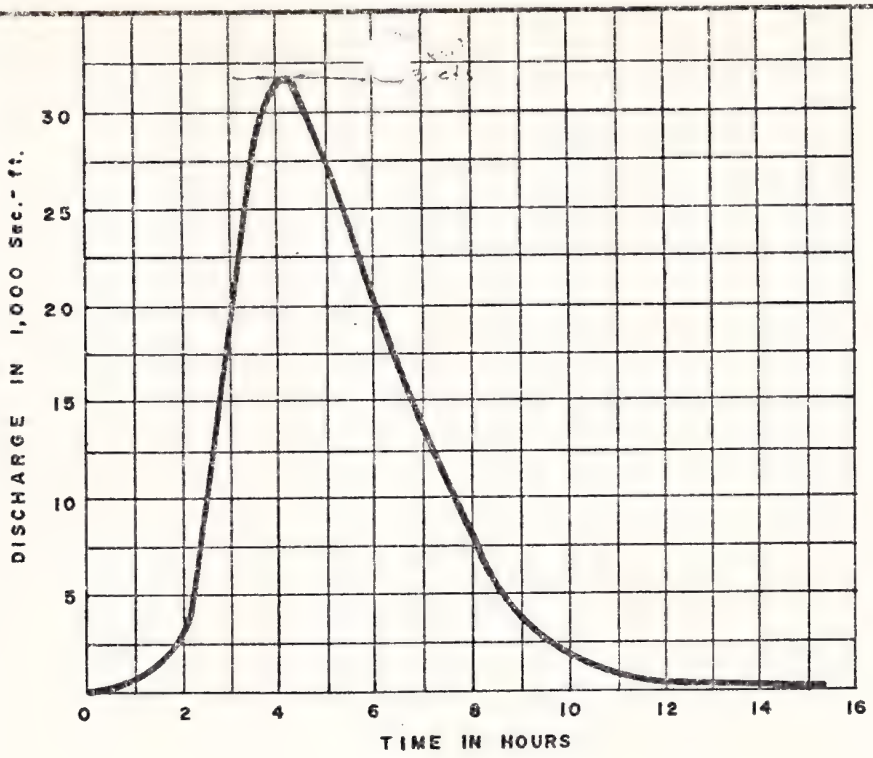
COMMONWEALTH OF PUERTO RICO
DEPARTMENT OF PUBLIC WORKS
& PUERTO RICO PLANNING BOARD

FLOOD CONTROL STUDIES, HUMACAO

SOILS BORINGS

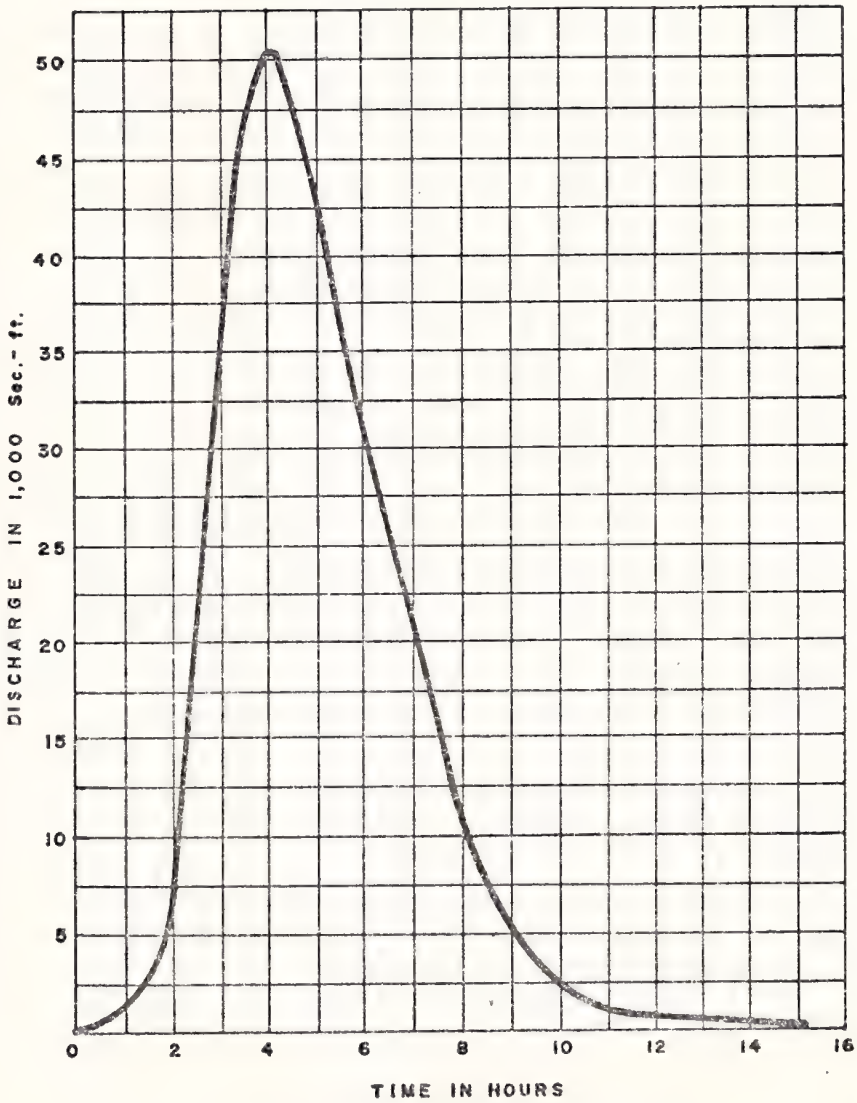
CESAR S. CANALS ASSOCIATES
CONSULTING ENGINEERS
SAN JUAN, PUERTO RICO | DATE: APRIL 196

PLATE 8



100 YEAR FLOOD

AREA = 25.6 Square Miles
6 Hr. POINT RAINFALL = 10.5"
AREAL DISTRIBUTION = 8.8"
RUNOFF (Condition III) = 7.9"
VOLUME =
7.9 x 53.33 x 25.6 = 10,785.5 Acre ft.



STANDARD PROJECT FLOOD

AREA = 25.6 Square Miles
6 Hr. POINT RAINFALL = 15.5"
AREAL DISTRIBUTION = 13.0"
RUNOFF (Condition III) = 12.0"
VOLUME =
12.0 x 53.33 x 25.6 = 16,383 Acre - ft.

THE PREPARATION OF THIS REPORT WAS FINANCED IN PART THROUGH AN URBAN PLANNING GRANT FROM THE DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT, UNDER THE PROVISIONS OF SECTION 701 OF THE HOUSING ACT OF 1954 AS AMENDED.

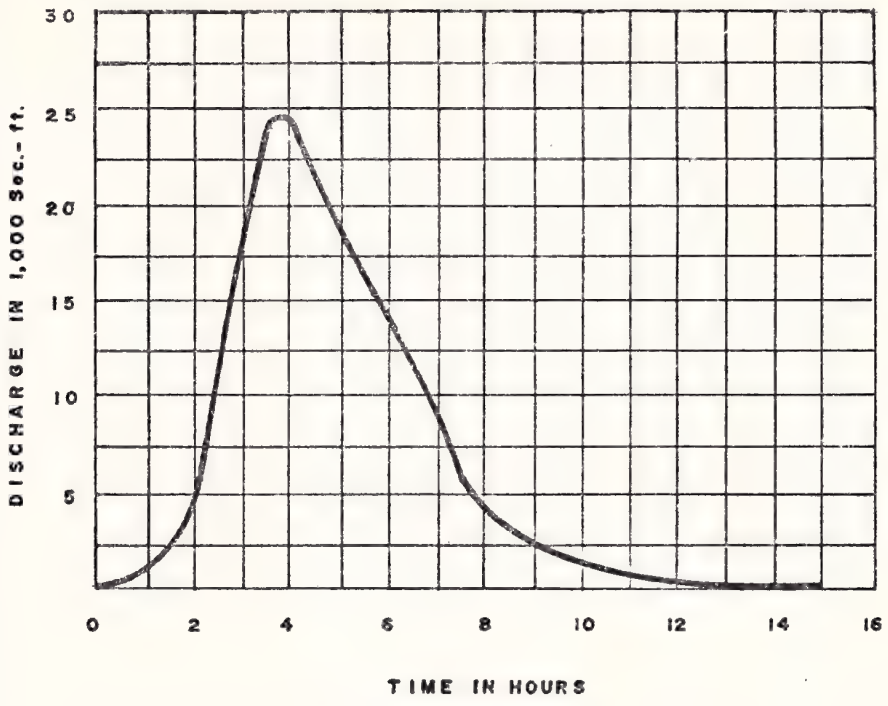
COMMONWEALTH OF PUERTO RICO
DEPARTMENT OF PUBLIC WORKS
& PUERTO RICO PLANNING BOARD

FLOOD CONTROL STUDIES, HUMACAO

SYNTHETIC FLOW HYDROGRAPHS AT MOUTH OF HUMACAO RIVER

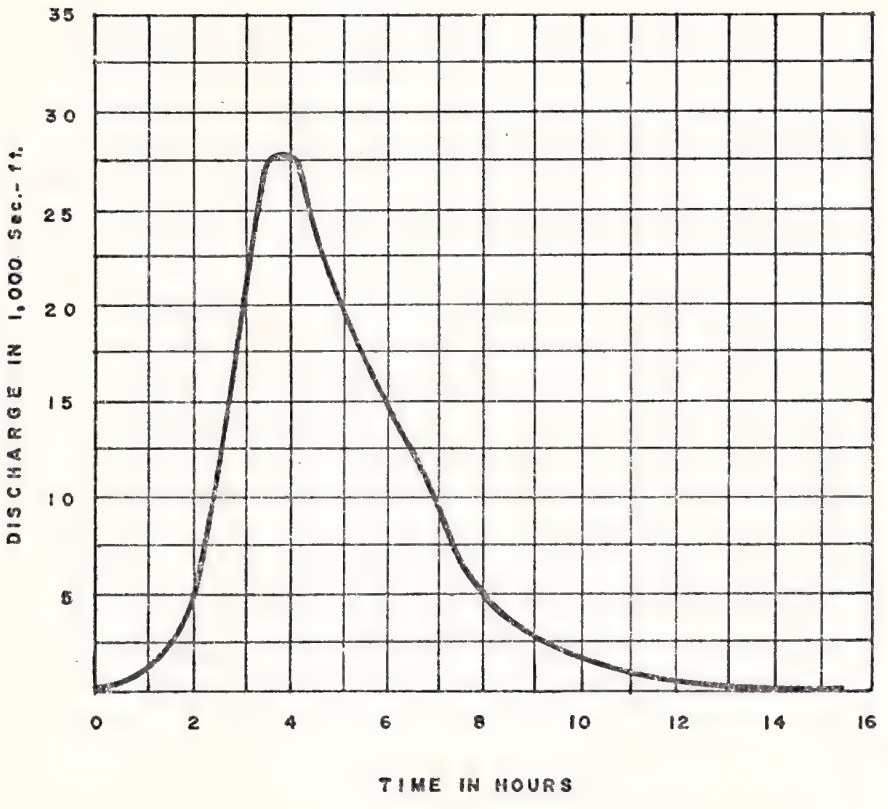
CESAR S. CANALS ASSOCIATES
CONSULTING ENGINEERS
SAN JUAN, PUERTO RICO

DATE : APRIL 1968



25 YEAR FLOOD

AREA = 25.6 Square Miles
6Hr. POINT RAINFALL = 8.1"
AREAL DISTRIBUTION = 6.8"
RUNOFF (Condition III) = 5.7"
VOLUME =
5.7 x 53.33 x 25.6 = 7,782 Acre-ft.



50 YEAR FLOOD

AREA = 25.6 Square Miles
6Hr. POINT RAINFALL = 9.2"
AREAL DISTRIBUTION = 7.7"
RUNOFF (Condition III) = 6.6"
VOLUME =
6.6 x 53.33 x 25.6 = 9,010.68 Acre-ft.

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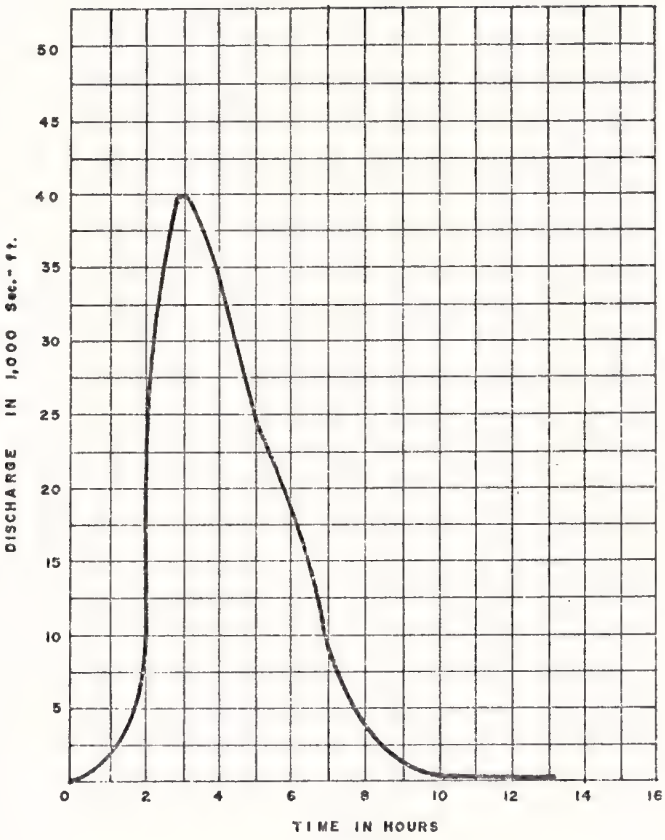
COMMONWEALTH OF PUERTO RICO
DEPARTMENT OF PUBLIC WORKS
& PUERTO RICO PLANNING BOARD

FLOOD CONTROL STUDIES, HUMACAO

SYNTHETIC FLOW HYDROGRAPHS AT MOUTH OF HUMACAO RIVER

CESAR S. CANALS ASSOCIATES
CONSULTING ENGINEERS
SAN JUAN, PUERTO RICO

DATE: APRIL 1969



AREA = 25.6 Square Miles
6Hr. POINT RAINFALL = 14.7"
AREAL DISTRIBUTION= 12.3"
RUNOFF (Condition II) = 9.3"
VOLUME =
9.3 x 53.33 x 25.6 = 12,698 Acre-ft.

SEPTEMBER 5-6, 1960 FLOOD

THE PREPARATION OF THIS REPORT WAS FINANCED IN PART THROUGH AN URBAN PLANNING GRANT FROM THE DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT, UNDER THE PROVISIONS OF SECTION 701 OF THE HOUSING ACT OF 1954 AS AMENDED.

COMMONWEALTH OF PUERTO RICO
DEPARTMENT OF PUBLIC WORKS
& PUERTO RICO PLANNING BOARD

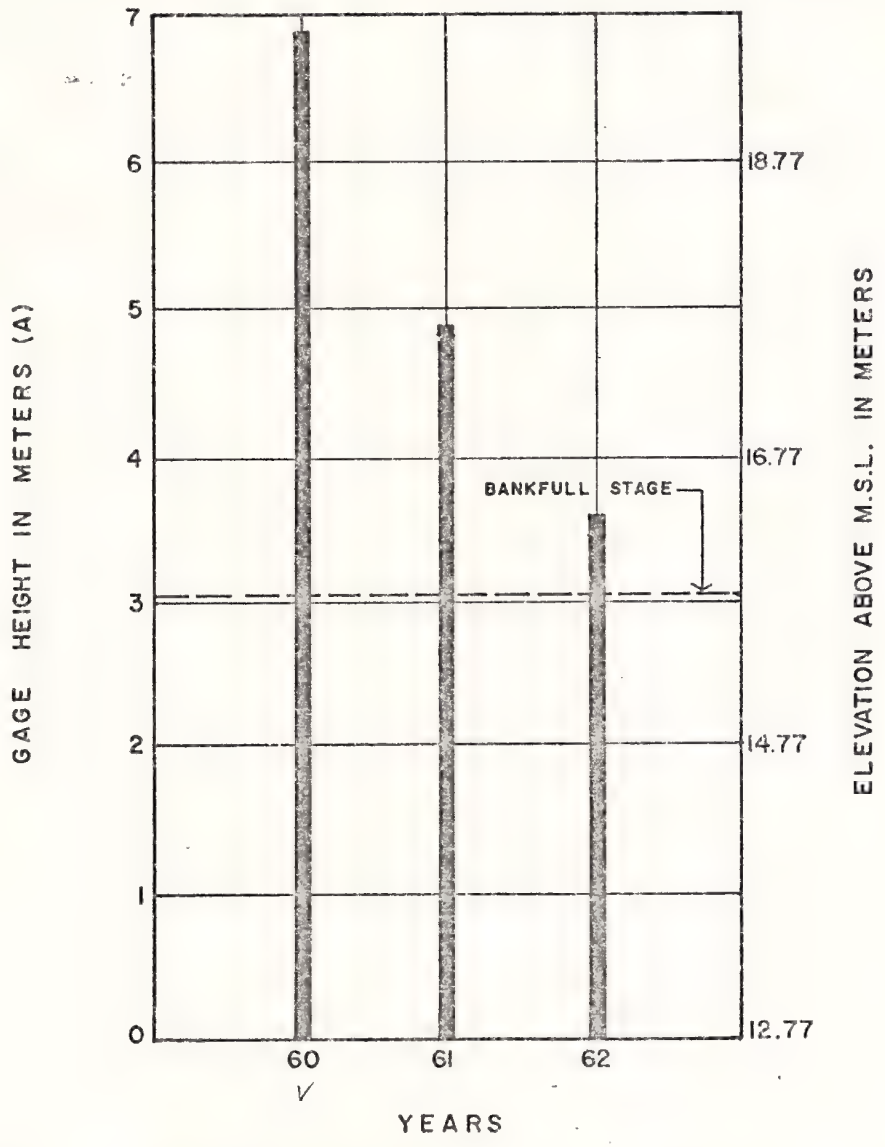
FLOOD CONTROL STUDIES, HUMACAO

SYNTHETIC FLOW HYDROGRAPH AT MOUTH OF HUMACAO RIVER

CESAR S. CANALS ASSOCIATES
CONSULTING ENGINEERS

SAN JUAN, PUERTO RICO | DATE: APRIL 1969

PLATE 11



(A) HEIGHT ABOVE BOTTOM OF RIVER

(B) STAGES FROM FLOOD MARKS

STAGES FROM FLOOD MARKS FOR THE 1960, 1961 AND 1962 FLOODS HEIGHTS WERE 18.9, 16.9 AND 15.6 METERS RESPECTIVELY.

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COMMONWEALTH OF PUERTO RICO
DEPARTMENT OF PUBLIC WORKS
& PUERTO RICO PLANNING BOARD

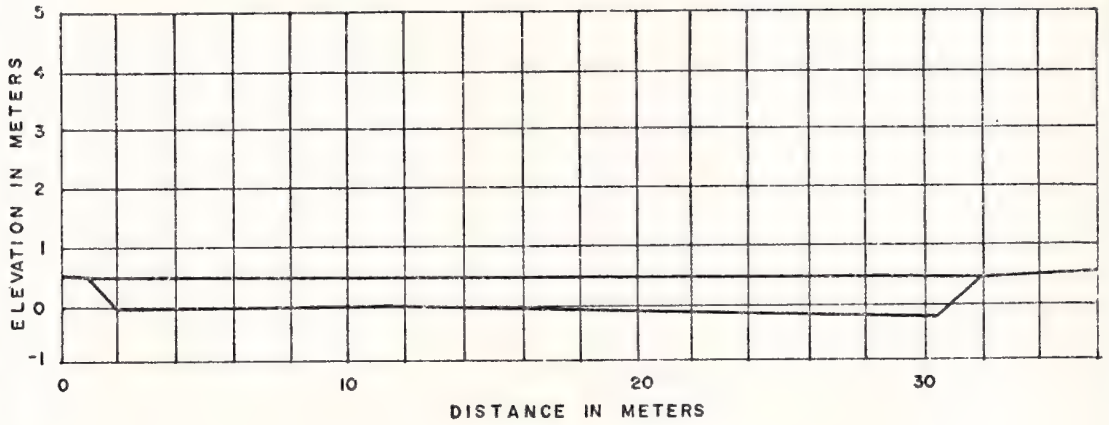
FLOOD CONTROL STUDIES, HUMACAO

FLOODS ABOVE BANKFULL STAGE HUMACAO RIVER AT BRIDGE ON ROUTE 3

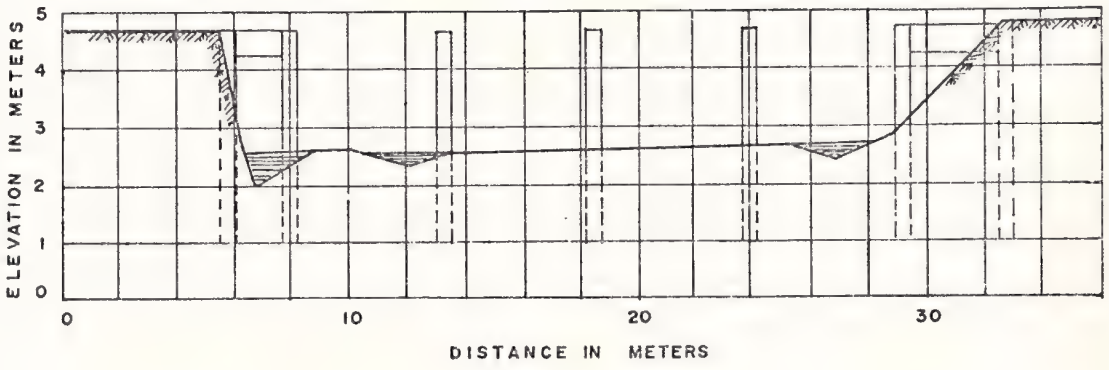
CESAR S. CANALS ASSOCIATES
CONSULTING ENGINEERS

SAN JUAN, PUERTO RICO | DATE: APRIL 1969

PLATE 12



*SECTION - 1



*SECTION - 2

* FOR LOCATION OF SECTIONS REFER TO INDEX MAP

THE PREPARATION OF THIS REPORT WAS FINANCED IN PART THROUGH AN URBAN PLANNING GRANT FROM THE DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT, UNDER THE PROVISIONS OF SECTION 701 OF THE HOUSING ACT OF 1954 AS AMENDED.

COMMONWEALTH OF PUERTO RICO
DEPARTMENT OF PUBLIC WORKS
& PUERTO RICO PLANNING BOARD

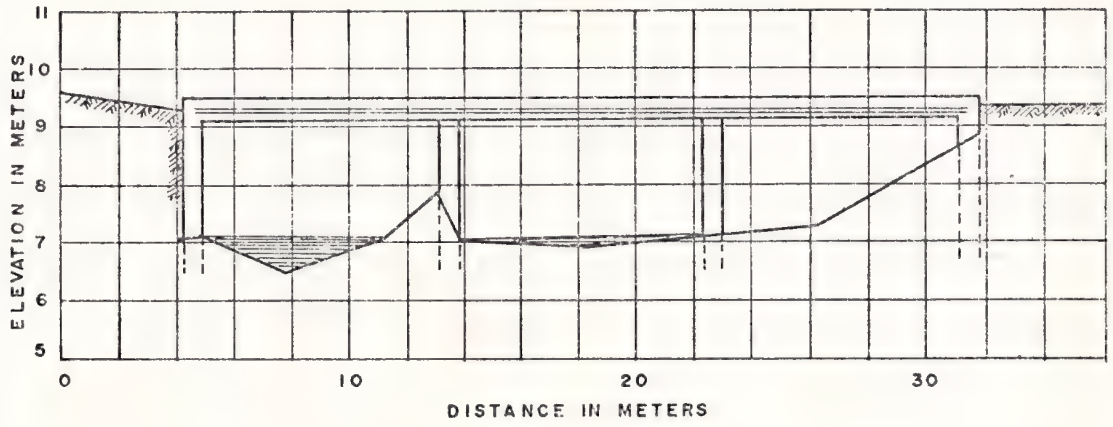
FLOOD CONTROL STUDIES, HUMACAO

HUMACAO RIVER SECTIONS

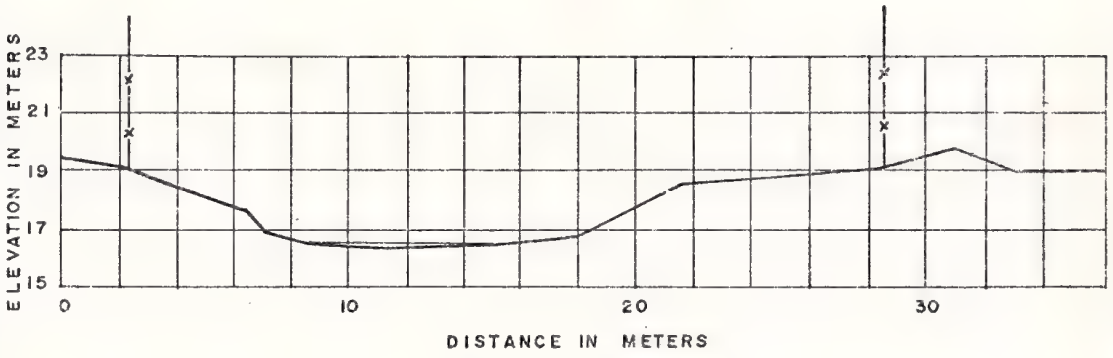
CESAR S. CANALS ASSOCIATES
CONSULTING ENGINEERS
SAN JUAN, PUERTO RICO

DATE: APRIL 1969

PLATE 13



*SECTION - 4



*SECTION - 8

* FOR LOCATION OF SECTIONS SEE INDEX MAP

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COMMONWEALTH OF PUERTO RICO
DEPARTMENT OF PUBLIC WORKS
& PUERTO RICO PLANNING BOARD

FLOOD CONTROL STUDIES, HUMACAO

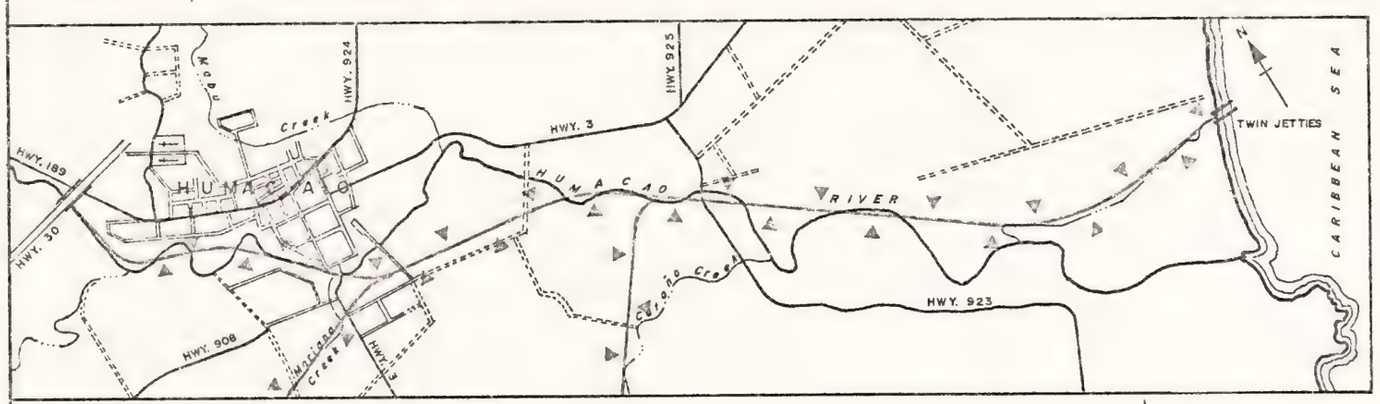
HUMACAO RIVER SECTIONS

CESAR S. CANALS ASSOCIATES
CONSULTING ENGINEERS
SAN JUAN, PUERTO RICO

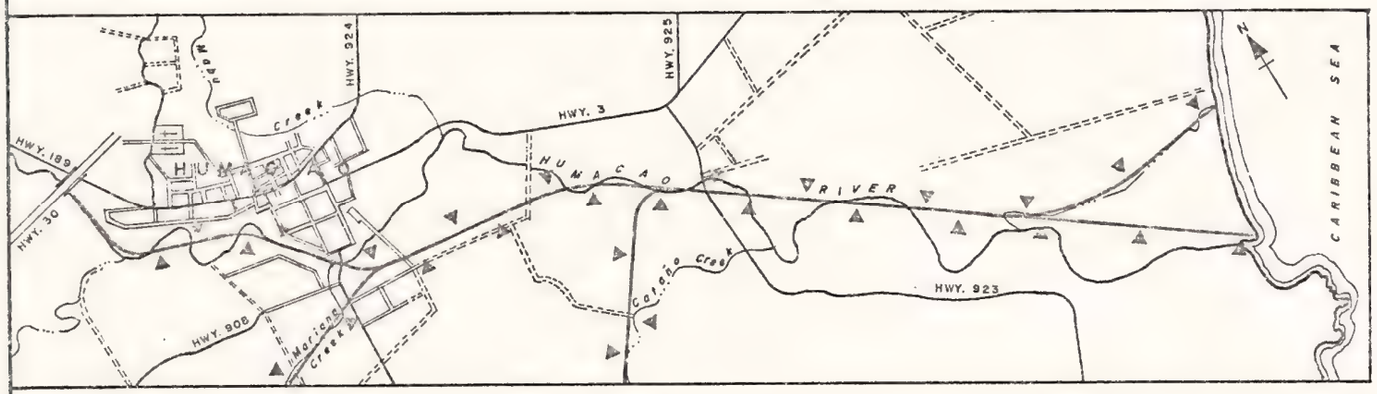
DATE: APRIL 1969

PLATE 14

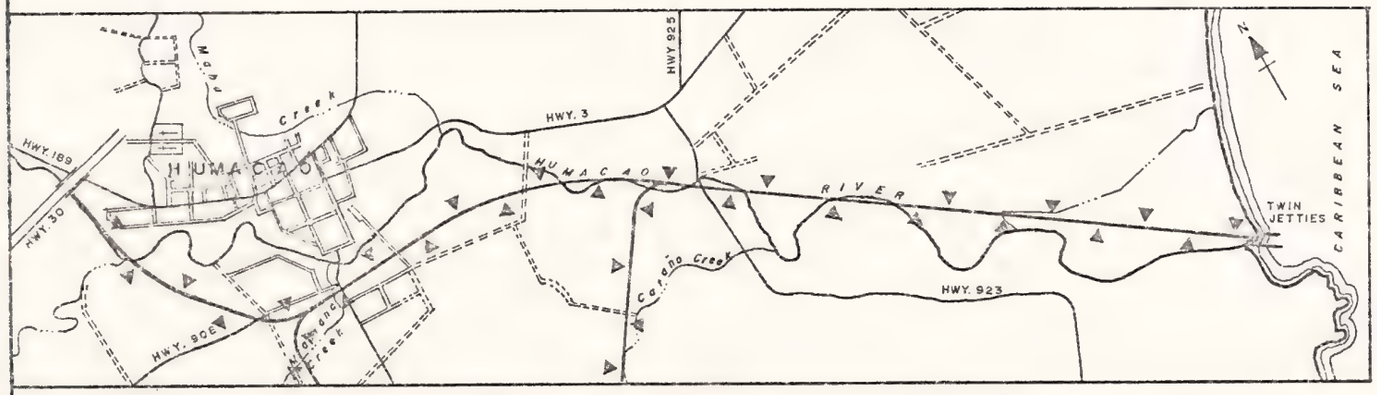
THE PREPARATION OF THIS REPORT WAS FINANCED IN PART THROUGH AN URBAN PLANNING GRANT FROM THE DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT, UNDER THE PROVISIONS OF SECTION 701 OF THE HOUSING ACT OF 1954 AS AMENDED.



PLAN - A



PLAN - B



PLAN - C

LEGEND

LEVEES

CHANNEL

500 0 500 1000

SCALE IN METERS

COMMONWEALTH OF PUERTO RICO
DEPARTMENT OF PUBLIC WORKS
& PUERTO RICO PLANNING BOARD

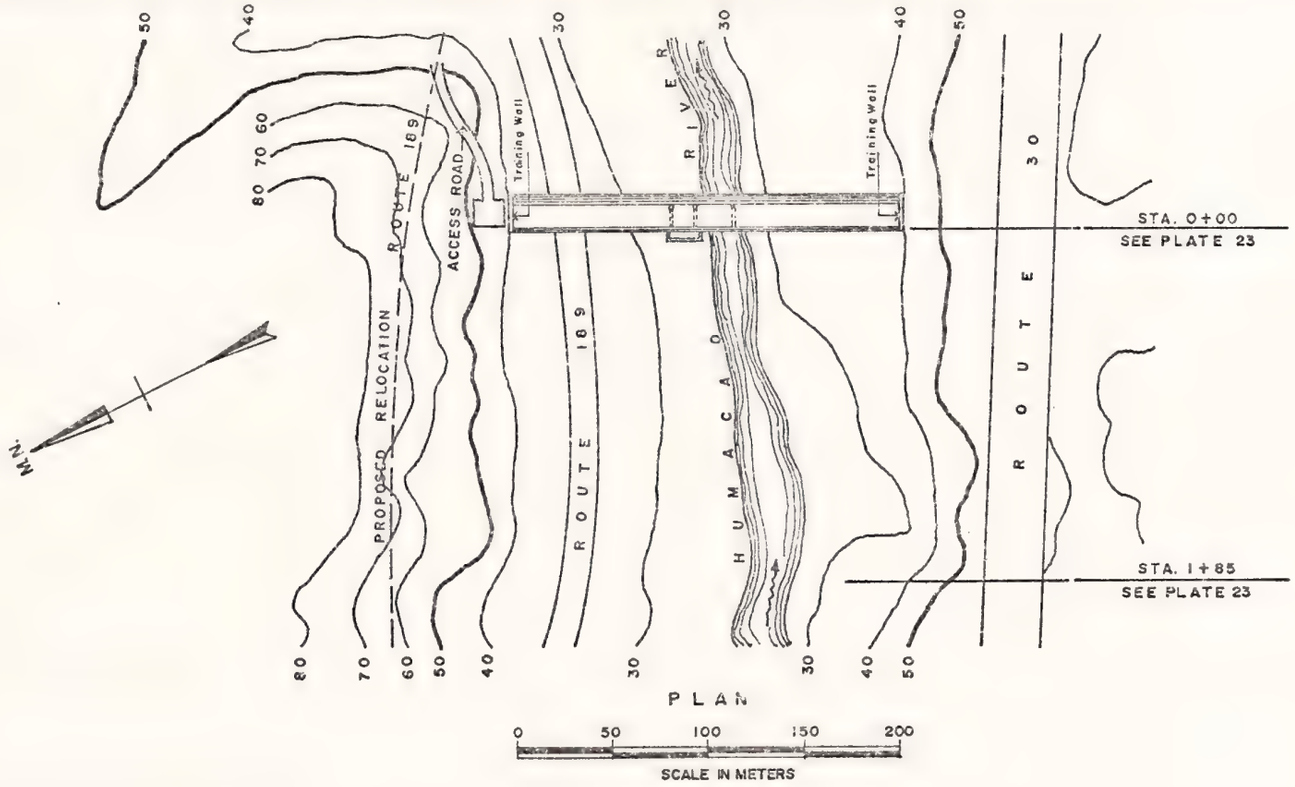
FLOOD CONTROL STUDIES, HUMACAO

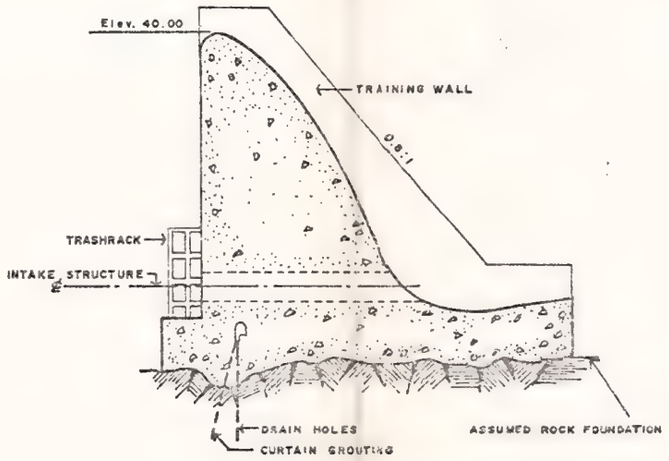
ALTERNATE PLANS OF FLOODWAY

CESAR S. CANALS ASSOCIATES
CONSULTING ENGINEERS

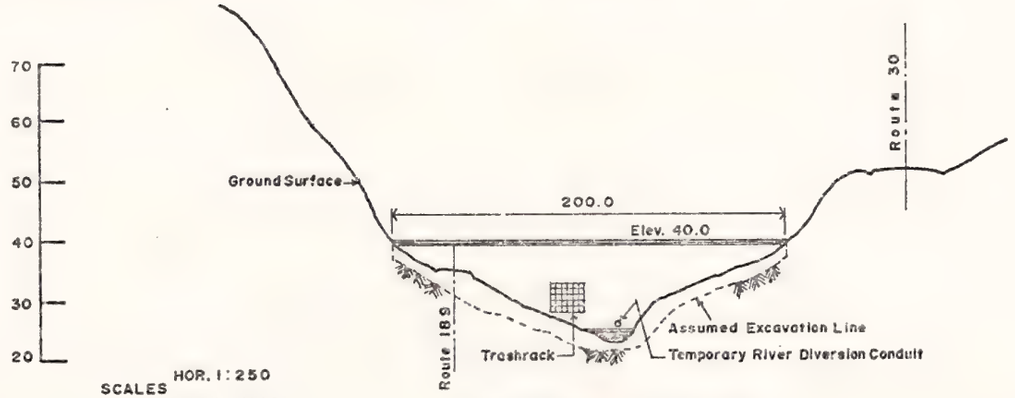
SAN JUAN, PUERTO RICO | DATE: APRIL 1969

PLATE 26





SPILLWAY SECTION
SCALE 1:400



SCALES HOR. 1:250
VERT. 1:800

UPSTREAM ELEVATION

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COMMONWEALTH OF PUERTO RICO
DEPARTMENT OF PUBLIC WORKS
& PUERTO RICO PLANNING BOARD

FLOOD CONTROL STUDIES, HUMACAO

DETENTION DAM
PLAN, ELEVATION & SECTION

CESAR S. CANALS ASSOCIATES
CONSULTING ENGINEERS
SAN JUAN, PUERTO RICO DATE: APRIL 1969

PLATE 25

View of the mouth of the river closed by sand accretion.

View of the remains of an old P. R. bridge destroyed by the 1960 flood. Taken looking upstream.

View of old P. R. bridge covered by bamboo trees and other vegetation. This bridge was partially destroyed by the 1960 flood. Taken looking downstream.

View of old bridge on Route 923 looking downstream. Destroyed during May 21, 1969 storm.

View of the remains of an old P. R. bridge destroyed by the 1960 flood. Taken looking upstream.

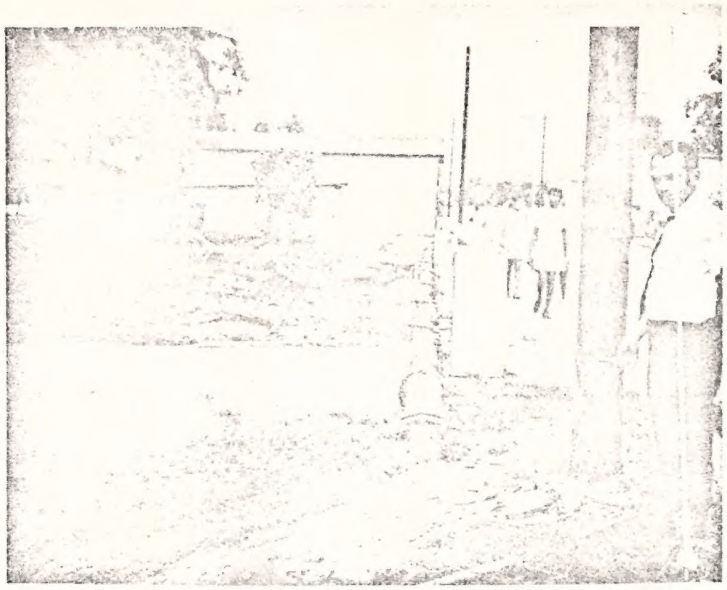
View of vine covered piers of old P. R. railroad bridge destroyed by the 1960 flood.

Bridge on State Route No. 3 built in 1961, after the 1960 flood washed away the old bridge at the site.

View of Cataño creek looking downstream from bridge on State Route 923.

View from the New Shopping Center in Humacao looking at a pedestrian crossing built by placing 36" concrete pipes across the river.

View of pedestrian crossing from south bank of the Humacao river to the new Shopping Center in Humacao.



Flood waters of the Quebrada Mariana in Humacao rose to the height indicated by the pencil in the pole.

Bridge on Route 923 in Humacao spared by the 1960 flood of the Humacao River was washed out on May 21, 1969.

View of the confluence of Mabú creek and the Humacao River swollen by floodwaters on May 21, 1969.